This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

ONE SHILLING

STANLEY'S PATENT
ELECTRIC DISC
&
100 Experiments
BY A POSITIVE CONDUCTOR

ELECTRIC DISC

AND

EXPERIMENTS.

ELECTRIC DISC

AND

EXPERIMENTS.

BY

A POSITIVE CONDUCTOR.

PUBLISHED BY
W. F. STANLEY, PATENTEE,
RAILWAY TERMINUS, LONDON BRIDGE.
1869.

196. f. 9.

Butler & Tanner,
The Selwood Printing Works,
Frome, and London.

PREFACE.

When I commenced this short treatise I intended to give a series of electrical experiments, part old, part new, calculated only to amuse. I intended to simplify the construction of the standard experiments so that they should cost pence and shillings, instead of pounds, and this would be all; but when I came to note the experiments down, I found that they would, if arranged, exemplify much of the known theory of electricity as a scientific investigation.

Recalling my school teaching of geography, that I learnt by heart, sentence by sentence from Goldsmith, with much mental labour, and which I forgot when I left school—to look around and discover that others better taught had gained more practical knowledge by the amusement of drawing maps and pointing out positions on the globe—So upon the *practical principle,* I have tried to make this a kind of map of electricity, whereby its wonderful properties and laws may be seen and remembered; by constructing or performing simply arranged experiments, which require little mental effort, reading, or study, and yet contain many *solid facts* and *principles.*

CONTENTS.

PAGE

Historical Sketch of Electrical Discoveries 1

Conductors and Non-Conductors 6

Induction 7

The Electric Disc 8

Leyden Jar and Discharger 12

Insulation and Insulators 15

Experiments which show the Effects of Electricity on the Human Frame 17

,, Which particularly show the Intense Heat of the Electric Spark 21

,, In Changing the Character and Colour of the Electric Spark 25

,, Showing Mechanical Effects of Electricity . . 30

,, Which show that Objects charged with like Electricity are Repelled from each other 34

,, Which show that particles of Air, when charged with like Electricity, are Repelled as other Light Bodies 37

,, Which show Alternate Attraction and Repulsion . 40

,, Producing various Luminous Effects with the Spark and Current 47

,, In the Luminous Effects of Electricity passing through various Gases, Rarefied Air, and Vacuum 56

,, Which illustrate the Theory of Electricity as the Active Agent in various Atmospheric Phenomena 62

,, Showing the Chemical Effects of Electricity . . 68

,, Showing certain Magnetic Effects of Electricity . 70

,, In the Measurement of Electricity 71

,, In the Separation of given Quantities of Electricity . 75

PAGE
Experiments to distinguish Positive from Negative Electricity . 77
,, To show the Distribution of Electricity on the surface of Conducting Bodies 79
,, To show the Action of Electrified Bodies upon Bodies in a Natural State-Induced Electricity . . 82
,, On Induced Electricity applied to Condensers . . 84
,, In Discharging, instantaneous and slow 85
,, Which show that Electricity is only retained by Non-Conducting Bodies 86
Secondary Charge—General Caution 88

THE ELECTRIC DISC,

AND

EXPERIMENTS.

OUR purpose is to describe the Patent Electric Disc and the experiments it will perform; but as this Electric Disc, although its small cost may bring it within the category of scientific toys, is really a powerful electrical machine, capable of performing nearly all the experiments of the most costly apparatus, we will endeavour to give so much of the theory and practice of electricity as may render our experiments instructive as well as amusing. The subject is so large that we dare not venture on much of the scientific ground; and surveying it, as it were, from a distance, with amusement as our particular aim, perhaps the least dry part of the subject by which we may introduce it, may be the *historical*—of this we can give only a light outline sketch; we shall thereby get a few causes and effects which will help us to make the matter of the experiments more comprehensible.

The old Arabian word *Karabe—amber,* signifies the power of attracting straws; so that we presume the first observation of electricity was made in a very early age. Our word electricity is taken from the Greek word *electron*—amber, because Theophrastus, B.C. 321, mentions the power of amber to attract straws and dry leaves, after it has been rubbed for some time on woollen cloth. This observation is the first recorded electrical experiment. It will be found amusing to repeat it; we cannot generally get amber, but a flat stick of sealing wax will answer, and the coat sleeve drawn smooth to the hand is a capital rubber. The sealing wax so excited will attract pieces of very dry paper or light feather from a surprising distance.

Our countryman Dr. Gilbert, physician to Queen Elizabeth, repeating this experiment in 1600, discovered that this attraction could be excited in many substances besides amber. He measured the power of attraction by a needle balanced in the centre, an instrument now in use for scientific electrical investigation. From these and many connected observations, Dr. Gilbert is considered as the founder of the science of electricity. He also made an observation on electricity which should be remembered in all our experiments :—"That when the wind blew from the north and east, and when the air was dry, that attraction was excited in a few minutes from the time that friction commenced; but that if the wind was south and the air moist, the attractive power of a body was greatly diminished, and in some cases it could not be excited at all." In modern practice we keep every portion of the apparatus dry and sufficiently warm that no moisture should settle upon it.

The first electrical machine, or that worthy of the name, was invented by Otto Guericke, about 1674; it consisted of a ball of sulphur fixed on a spindle to turn with a handle, the hand being pressed on the ball to produce the friction necessary to excite electricity. This machine first produced the electric *spark,* which was accompanied with *sound;* this made a startling advance in the wonders of the new science. Otto Guericke also discovered that a body attracted by electricity, would, after it had touched for a short time to become charged, be repelled by the same excited object that had at first attracted it. This we shall see is the electrical law that governs many of our experiments.

Sir Isaac Newton, about 1675, constructed a machine like Otto Guericke's, but with a glass globe in place of a sulphur one; this produced sparks a quarter of an inch long, which sparks would fly off the globe if any one applied his finger, and could not only be seen but *felt*.

Mr. Stephen Grey, about 1720, discovered that the electricity could be conveyed by a wire or wet thread from the machine to a body at a considerable distance; he also discovered that it was the surface of bodies only that were excited by electricity, and that the amount of developed electricity would be the same whether the body were solid or hollow.

M. Dufay, 1733, found that all bodies could be electrified from the machine by setting them on a stand supported by glass rods, if the glass rods were kept dry. If a person stood on the stand and was electrified, that sparks would issue with a snapping noise from any part of his body, nearly touched by the finger of another person. His most important discovery was that there were two kinds of electricity, one kind excited upon glass and other vitreous substances, which he called *vitreous*; and the other excited upon resin and other kindred substances, which he called *resinous*;—thus in experiment if we hang a small pith ball by a fine silk thread, and we now rub a rod of glass upon a piece of silk and bring it near the ball, it will be attracted by the glass until it touches, after which it will be repelled from the same glass; but if we now bring a stick of resin (sealing wax) similarly rubbed, the ball that was repelled by the glass rod will be attracted by the sealing wax one until it touches, and then be repelled again—after which the glass rod will again act as at first, and so on alternately. This is by itself a rather pretty experiment, and shows a theory the equivalent of which pervades all other electrical experiments.

Up to about 1736, Newton's machine was still used, the pressure of the hand being applied to excite the machine. At about this date, Professor Winckler of Leipsic discovered that a pad of horsehair covered with silk or leather answered better than the hand. This discovery enabled machines to be made of much higher power. There was still a great difficulty, electricity could be produced, but it could not be kept from flying off the machine, until Professor Boze of Wittemberg, about 1738, discovered that a tube of metal held near the machine would collect a considerable amount. This invention was the prime conductor which is applied to all machines. It is very amusing how the experiment was first managed. The professor had a cask of resin placed near his machine, and a man standing on the cask held the tube in his hand against the machine, and thus collected the electricity; it would perhaps now be difficult to get a man to stand as a part of the prime conductor, as the sensation long continued, would not be very pleasant. However, it is not necessary, as the professor afterwards found that a piece of glass rod answered much better for a support. It was soon discovered that this tubular prime conductor required rounded ends, as electricity soon disappeared if there were any sharp edges or points in connection with the conductor.

The machine had now assumed its present form, and wonders were performed with it. Spirits of wine were ignited by a spark proceeding from the point of the finger; gunpowder was exploded by a spark from a pointed piece of ice. Abbé Nollet gave an electric charge through an entire regiment of 1500 men, who all received a violent shock through the arms and shoulders.

Having the electrical machine now of a construction which, with the combined improvements and inventions enumerated, and some others of minor detail, would produce quantities of electricity only limited by the size of the machine and the power to work it, the next great object was to find some means of storing it up and concentrating it; this was eventually done by the Leyden jar, which appears to have been the invention of several scientific investigators. It passed through many changes and improvements before it reached its present form; commencing a simple bottle of electrified water, and finishing as a powerful battery, which we shall have to describe, capable of producing sparks twelve to twenty inches long.

By relating the above separate discoveries in electricity, we feel sure the theory of many of our experiments which follow will be in some way explained, because each separate discovery points out some property peculiar to electricity; and it so happens that we know nothing of electricity except its peculiar properties. It was thought at one time, amongst other theories, that it was a peculiar fluid, and that when we saw the spark we really saw the *electricity*; we now know that we only see the heating effect of electricity, and that the spark is simply particles of the conductor, whatever it may be, rendered incandescent. In some instances the particles are ignited, in other instances only the exterior portions of the particles are ignited, the interior being simply fused; thus the spark from a gold conductor will by a certain arrangement leave a portion of the fused gold on the surface of a silver conductor to which the electricity passes. This property of ignition of particles of the conductor is made the source of beautiful experiments in glass tubes containing a very small quantity of air or other gases in a large space, the particles of gas being made the conductor, and being extremely minute they become highly incandescent, and exhibit beautiful colours according to the nature of the incandescent gas, as some of the experiments to follow will show.

It was mentioned that Grey discovered the power of certain bodies to conduct electricity. It will be necessary to define this part of our subject distinctly, as we shall often refer to it.

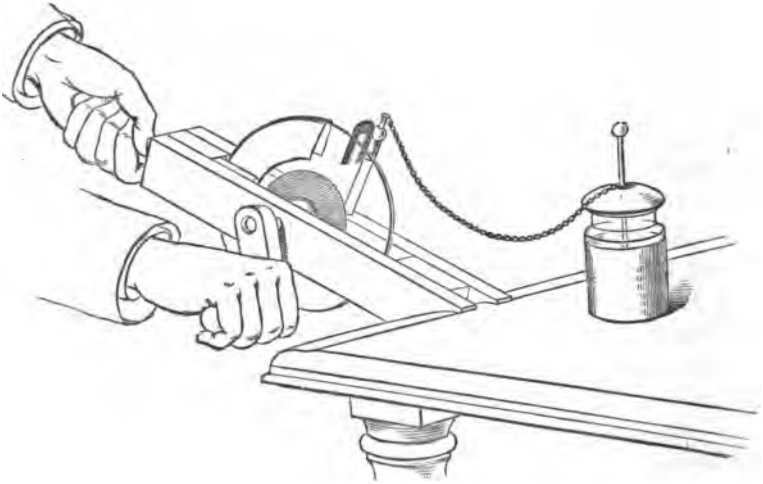
CONDUCTORS AND NON-CONDUCTORS.—Every known substance conducts electricity in a relatively assignable degree; but this power varies extremely; thus, electricity will pass over metal many thousand miles in a second of time, whereas it is supposed scarcely to enter the surface of glass the fiftieth part of an inch, or in dry air spread an inch over its surface. For this reason non-conducting substances are also called *insulating substances,* as the conducting power of a body may be surrounded by a non-conducting body, and *insulated* in such manner that the electricity will scarcely pass. We will give a list of a few substances useful for experiments, which we will divide into three classes.

CONDUCTORS.	BAD CONDUCTORS.	INSULATORS.
Metals	Alcohol and ether	Shellac
Charcoal	Dry wood	Sulphur
Black Lead	Paper	Resin and Wax
Acids	Ice at 32°	Glass
Water	Dry cotton or linen	Caoutchouc

INDUCTION.—This is a peculiar property of electricity acting upon conductors which are insulated from the earth; by which an insulated conducting body, placed at a distance too great to have electricity conducted to it from another body charged with electricity, yet will have influence to manifest electricity in it, in such a manner that the part of the insulated conductor farthest from the charged body will exhibit the same kind of electricity as the charged body, but in less degree; whereas the part of the insulated conductor nearest the charged body which influences it will be of the opposite kind of electricity. We will recur to this technical subject after some connecting effects have been practically shown.

Thus far we have only travelled a short distance in electricity, and of electricity in one branch only, that excited by friction: there are other divisions of the subject in which the electricity is excited by *chemical action*, by *magnetism*, and by *heat;* these will be left entirely alone, and are only mentioned to show the restricted division of experiment which we undertake.

For the certain success of our experiments we must call again to mind Dr. Gilbert's remarks,—" When the wind blew from the north and east," etc., and particularly remember to have our apparatus dry when we are about to use it: it will be found a capital plan to lay the whole of it on a rug in front of the fire for an hour before commencing our performances.



ELECTRIC DISC.

THE MACHINE which is illustrated above consists of an arrangement of the separate parts of which we have given some particulars of the invention. A disc of glass revolves by a handle; against the surfaces are two rubbers of horsehair covered with leather; it has been found that these rubbers will excite electricity more quickly if spread with an amalgam of mercury and tin mixed with tallow, which is done in this machine, so that it will last without renewal for some time. The electricity, as it is developed on the glass by the friction of the rubbers, is carried over by a kind of sheath technically called *the apron* to a series of collecting points which communicate with the prime conductor, which in this machine is reduced to a small ball, but in other electrical machines is a large tubular affair; the prime conductor is insulated from the machine by a rod of glass. It is to the hole in the prime conductor that we connect all our experiments.

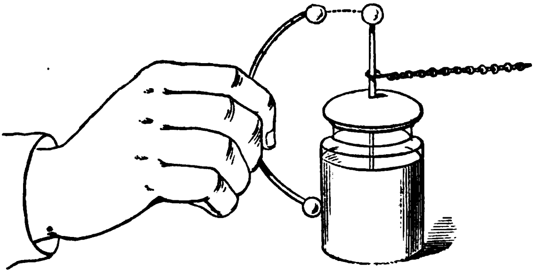
To produce electrical currents with the machine.—The machine should be examined to see that the glass rod of the prime conductor is clean and dry, and stands firm in its hole; that the collecting points stand square to the machine, and are set so that they are at about equal distance from each side of the glass. The fixed handle of the machine should now be taken in the left hand, and the forked end of the machine pressed against the extreme edge of the table; it is best to place the hand firmly against the body. If the handle of the disc be now turned steadily and firmly with the right hand, the electricity will be quickly developed, and will fly off in sparks from the knob of the prime conductor if another person place his knuckles near it while the turning continues; or it may be taken by the operator himself, if the handle of the frame is rested against the body so as to have the left hand free; the machine will hold firmly to be turned in this way, particularly if a handkerchief folded several times be placed over the end of the handle. The spark shows that the machine is in working order, and may now be applied to any experiment: the very slight sensation of taking the spark is caused by the smallness of the prime conductor, with a larger prime conductor the spark would be more intense but less frequent.

To keep the machine in order.—After the machine has been in work some time the glass will be covered with streaks of the amalgam from the cushions. If any of these are dense and cloggy they should be rubbed off with a piece of cloth, and a little tallow be rubbed on the place. If the machine does not now develop sufficient electricity, it will be necessary to re-amalgamate the cushions. This is done by unscrewing the side of the machine and taking out the disc. The amalgam is to be mixed with grease and spread upon the cushions very thinly with a dinner knife; when the machine is again put together, care must be taken that the screw to the cushions be not turned too tightly to break the glass, the pressure must nevertheless be sufficient to cause the handle to move rather stiffly; it will be best to adjust it gradually, and to try the effect continually by charging the Leyden jar several times, as increase of pressure is given; the proper pressure may thus be easily obtained.

THE CHAINS. *The machine chain.*—All metals conduct electricity. To convey the electricity collected upon the prime conductor, we make use of a chain; the one provided for this purpose, which we will uniformly call the *machine chain,* has a short stout pin attached to one end and a hook at the other, the pin fits into a hole on the top of the ball of the prime conductor, and the hook may be attached by lightly putting it over the part directed in our experiment. When the chain is in use it should be led away from the surface of the glass plate of the machine as direct as possible to where it is required; it should never hang to touch the table, nor any other part of the experiment or other object, except that particular part of the experiment to which it is applied. The chain, when the machine is excited, will carry off the electricity to any object near, and we may if not careful lose it all. Experiments occasionally become overcharged; for this reason it is better, if an experiment does not act as it should, to let the chain hang loose for a second, to unite the excited surfaces, and to re-commence the experiment.

The ground chain.—The earth is called the common reservoir of electricity, because when electricity is conducted to it in any manner, it immediately disappears without leaving any trace. The ground chain is a piece of chain with a hook at both ends. It is used to convey electricity to the earth or to the outer coating of the jar. When we say to the earth, it must be particularly observed through all experiments, we mean to any conducting body in connection with the earth; thus if the chain is laid on the table, the table is connected to the floor, and the floor to the walls, and the walls to the earth, thus electricity would be conveyed; but if the chain were laid on a plate on the table no electricity will pass; if the table is French polished and covered with a dry woollen cloth, electricity will pass with difficulty, because these last-named substances do not conduct electricity well. These observations are particularly to be borne in mind if we wish to succeed with many experiments. A young friend had an electrifying machine given to him, together with several experiments; he wrote to the writer of these pages that he could not perform several of his experiments by following exactly the instructions.; these the writer saw immediately were those requiring the electricity to be conveyed to the earth. Not being able at the time to inquire into the cause, he directed him to connect some fine wire which he sent, from the experiment to a gas or water pipe; this gave certain conduction to the earth. Subsequently visiting the young experimenter, the whole cause of his mishap was discovered; he had tried his experiments on the dining-room table, which stood upon *porcelain castors* that insulated it from the earth.

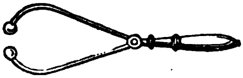
The free chain.—This conductor is used to convey electricity from any experiment to the knob of the Leyden jar, when the ground chain is used to convey the electricity from the outer coating; the machine chain being used at the same time to fill the jar.



LEYDEN JAR AND DISCHARGER.

THE LEYDEN JAR.—This is, as explained, a condenser or accumulator of electricity. It consists of a glass bottle, covered with tinfoil internally and externally over about three-fourths of its surface up from the bottom. The bottle has a dry wooden cap fitted to it. Through the cap a small rod of metal is passed, which terminates at the lower end with a piece of chain which is allowed to rest on the tinfoil surface at the bottom of the bottle; the top of the rod terminates with a metal knob.

To charge the Leyden jar.—For this the knob of the jar may be held near the prime conductor of the machine while it is being turned, taking care that the hand touches only the outer tinfoil coating of the jar; or the chain from the machine may be attached to the rod below the knob. It is necessary to observe, if the weather is moist that the cap should be removed, and the jar, warmed inside by the fire. It is well in charging generally to lay the ground chain against the jar, if it is not held in the hand. If the whole apparatus is in good order the jar will sometimes overcharge and give a loud report, as the positive or vitreous electricity on the inner coating meets with the negative or resinous electricity on the outer coating.

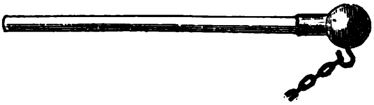


DOUBLE-JOINTED DISCHARGER.

THE DISCHARGING ROD is a bent wire, terminating at each end with a ball; it is shown in our cut on the last page in the position it is held against the jar. This discharger is what is termed *simple*. The *double-jointed discharger* is shown in the above cut; this last allows the balls to be brought to any distance from each other, and is more convenient for many experiments.

EXPERIMENT 1.—*To discharge the Leyden jar.* After a few turns of the machine, connected by the chain or held by the hand as directed, the jar will be charged; now place one end of the discharging rod against the outer coating of the jar, and bring the other knob of the rod slowly to the knob of the jar; when it is within a short distance a spark will pass with a report, and the jar will be discharged. The outer coating of the jar may be touched at any time by the hand, without any electricity passing from it; by this means we may carry the jar to a distance to discharge it.

The length of spark or electric charge from the Leyden jar depends upon the quantity of surface coated with tinfoil; thus the larger the jar the longer and more intense the spark, and the more powerful the general electrical phenomenon connected with it. However, in practice it is found inconvenient to have a very large Leyden jar; the better plan is to have several jars, four, six, or nine are used generally, the inner coatings are united by means of a chain or rod from knob to knob, and the outer coatings by standing the jars on slips of tinfoil or thin metal. The intensity of the charge is just the same, according to the extent or surface of foil, whether it is in one or in many jars united. It is generally found most convenient to use a single jar up to one square foot of coated surface; above this a battery is equally convenient, and if plainly constructed less expensive.

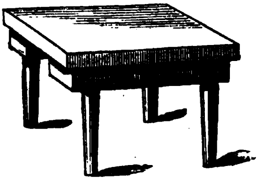


THE DIRECTOR.

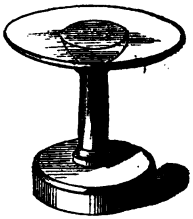
THE DIRECTOR.—This is used as a discharger, when the electricity is required to pass through an experiment previously prepared. It consists of a rod of glass, terminating with a metal ball, upon which a small hook is attached to take the chain.

To discharge the Leyden jar with the director.—As this is required to be done through so many experiments (which can only be noticed as *passing the charge*, without constant repetition), it will be necessary to observe the manner in which the charge is uniformly passed. Having prepared our experiment, the ground chain is first connected to a conductor of the experiment by one of its ends, and the other end of the chain is connected with the outer coating of the jar, either by laying it against the coating, or what is generally better by standing the jar upon a portion of it. The free chain is next connected to the second conductor of the experiment by one end, and to the director by the other. When the experiment is thus ready the Leyden jar should be charged by the chain from the machine. The charge is now passed through the experiment by bringing the knob of the director to the knob of the jar. If the experiment is properly arranged a spark passes between the knob of the director and jar, with a bright flash and snapping noise; but if the experiment offers too much resistance, so that the electricity will not pass, the knobs only give a faint light and a blowing noise. The experiment must then be re-arranged with less distance between its conductors, where broken, or greater surface of jar or battery.

INSULATING STOOL.—Any object charged with electricity from the machine disperses it quickly or slowly, according to the nature of the conductors in contact. As we have said, all substances conduct electricity; but there are many which conduct it very slowly, as dry atmosphere, vegetable gum, India-rubber, gutta-percha, shellac, glass, silk, etc. Thus, if we wish to charge an object with electricity we can do so by insulating it, that is by supporting or surrounding it by one or other of these substances. The insulating stool is one of these means; it consists of the ordinary four-legged stool, the legs being of stout glass; upon this we can place any experiment which we wish to electrify, and if the legs of the stool be dry we shall lose very little of the electricity, except that which is dispersed in the atmosphere, or more particularly by the vapour it contains. With our No. 1 and 2 machines we have an insulating



INSULATING STOOL.



INSULATING TABLE.

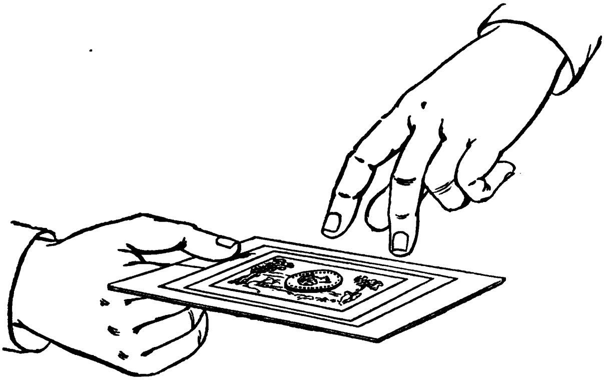
stand which consists of a glass pillar with a hole at the top to attach experiments, also a metal stand attached to the same foot-board which connects experiments with the ground; this stand enables us to perform many experiments, which are generally performed inconveniently attached to the electrical machine, or held in the hand. There are many simple means of constructing temporarily an insulating stand, which we will now suggest, as they will give an idea for other experiments, than for those of which we particularly indicate the scientific practice. Thus a person may be insulated from the floor conveniently on four dry tumblers, placed as legs of a stool, of which a stout folio volume forms the top, or by standing in a large dry dish or pan. Experiments may be insulated on one or more tumblers, bottles, or wine glasses, a sheet of glass, gutta-percha, or India-rubber, a cake of pitch, or a dry silk cord.

With these preliminaries we will now proceed more directly with our experiments, which we have attempted to classify for special *action* or *object*; the attempt may connect some of the phenomena, and it is hoped be convenient for reference; but the manifestation of electricity is so general in its action that we shall often detect the impossibility of separate classification. Take for instance *luminous experiments :* we find nearly all experiments are luminous in a degree, therefore our class *luminous experiments* is only intended to indicate that one quality of the experiments is *luminosity;* there will be also many other experiments which are luminous, which we shall classify for some other purpose; as for attraction or repulsion, this being in the given instance the more peculiar phenomenon of the special experiment.

EXPERIMENTS WHICH SHOW THE EFFECTS OF ELECTRICITY ON THE HUMAN FRAME, ALSO ITS CONDUCTIVITY.

Experiment 1.—*To give a shock to one person.* Let the person to whom the shock is to be given hold the Leyden jar by the tin foil coating in his right hand, and place the knob of it against the prime conductor of the machine while the machine is being worked; the jar will quickly charge. If he now remove the jar from the machine, and place one finger of his left hand against the knob, a shock will pass through his body. It is optional whether the jar is discharged at once: it may be, if required, set down on the table. It will remain charged a long time. Another person taking it up with one hand and touching the knob with the other will receive the shock.

Experiment 2.—*To give a shock through the arms and chest of a number of persons.* The company must take hands to form a chain. Let the person at one end of the chain take in his hand the Leyden jar, lately charged as directed, by the outer coating. If the person at the other end now touches the knob of the jar, the quantity of electricity contained will pass through the company, and give a shock, according to the size of jar: that supplied with No. 3 machine will give a very slight shock; that supplied with No. 2 moderate, if fully charged; that with No. 1 machine a rather unpleasant shock: with this last set of apparatus the lightning jar may be used as a Leyden jar, to give a shock sufficient to be agreeable for one person.



THE MAGIC PICTURE.

Experiment 3.—*The magic picture.* This experiment is a modification of Franklin's pane; it is intended to give a slight shock to one person, by getting him or her to hold the picture either by the foil or flat on one hand, and to touch the coin with the other hand. In construction it consists of a piece of glass with a sheet of tinfoil cemented on each side, of about an inch less in size every way than the glass. On one side a piece of foil is brought over to the edge of the glass, on the reverse side a picture is pasted over the foil. The coin is placed on the picture, and charged by the chain from the machine. It may be conveyed to any person without the electricity passing, if it be held by one corner.

Experiment 4.—*To charge a person with electricity,* *so that sparks may fly from his body when touched, and his hair will stand on end.* For this experiment we require either No. 1 or No. 2 machine, and an insulating stool or some equivalent, a quite dry, clean, large dinner dish will answer pretty well, or the tumblers and book described. This experiment should also be performed in a dry warm room. The person to be electrified must stand on the insulated stool, without shoes; he should be careful that no part of his body or clothing touch any article of furniture or other object. If he now take the chain of the machine in one hand, and another person turn the machine steadily for a few minutes, the insulated person will become charged with electricity, his hair will begin to rise, and sparks will fly from his body when touched by another person. There is no danger in this experiment, and very little sensation but that of heat, except that when touched, the sparks passing cause a prickling sensation.

Experiment 5.—*To draw sparks from a glass of water to the finger.* Let the chain from the machine be sunk into a glass of water, by tying a coin to the free end of it by a piece of thread, and let the machine be worked. If any person now apply his finger to within a short distance of the surface of the water, sparks will issue from it to his finger, with a snapping noise. The water will be luminous in the dark.

Experiment 6.—*To inflame ether with a spark from water to the finger.* Take a glass of water, and place the chain as before; now pour gently on the surface of the water a large tablespoonful of warm ether; if the machine be worked, and the finger be brought near to the surface, a spark will pass and the ether will be ignited. This experiment is generally given as setting fire to a glass of water.

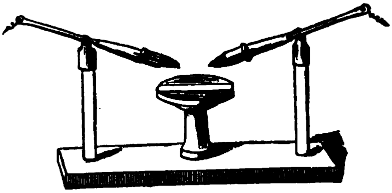
Experiment 7.—*To ignite ether with the top of the finger.* Immerse a tablespoon in hot water about 150° Fahrenheit for a few minutes, wipe the spoon perfectly dry, pour into the bowl sulphuric ether sufficient to about half fill it. Let this be presented to a person insulated upon a stool, and charged with electricity as already described. If he now point his finger over the bowl of the spoon about a quarter of an inch above the ether, a spark will pass, and the ether will be ignited. This experiment can only be performed with No. 1 machine, except the air be very dry.

Experiment 8.—The last may be varied by letting the insulated person hold the spoon, in which instance it should be presented to him by placing it on a dish; if it is given to him by hand the electricity will pass from him. The insulating person holding the spoon, the ether may be ignited by the point of any other person's finger. There are many substances which may be ignited by the point of the finger in this manner, as phosphorus, nitre, paraffin, etc. As the spoon and the finger only answer the purpose of conductors, they may be replaced by any other conductors, at the option of the experimenter.

Experiment 9.—*The gentle swan.* This experiment illustrates the conductive power of the human body. A

small glass or cork swan is placed in a dish or pan of water. If a person be insulated upon the stool or other means we have indicated, the swan will follow his finger in any direction as though it were a magnet, and the swan of iron. The experiment is generally amusingly performed by offering a piece of bread to the swan, which being electrified through the body acts the same as the finger.

Experiment 10.—A variation of the above may be made by insulating the dish of water, and charging the water with electricity; the swan will then follow the finger of any person not insulated. Variation is also made by constructing floating model duck and ducklings, mermaids, ships, etc., to fancy. This and the last require very little electricity, and may be performed with No. 3 machine.



UNIVERSAL DISCHARGER.

EXPERIMENTS WHICH PARTICULARLY SHOW THE INTENSE HEAT OF THE ELECTRIC SPARK. For the greater part of these experiments we require what is termed a universal discharger, which is constructed as follows. A piece of wood about ten inches long has a hole near each end, into which is inserted with cement a glass rod generally about four inches long. On the top of each rod a brass cap is fitted, a part of which forms a universal joint, which carries an adjustable rod, that terminates at one end with a loop, and at the other with a pair of forceps. A small insulated table is fixed in the centre of the board, which is so arranged that the points of the rods or *dischargers* described, may meet upon it. The forceps of the dischargers are required to hold various substances or pieces of apparatus; they have generally supplied with them a pair of metal balls, a pair of points, pieces of charcoal, etc.

Experiment 11.—*To explode gunpowder.* To effect this conveniently, we require the universal discharger just described and a charged Leyden jar. The powder to be exploded is placed on the insulated table between the points of the dischargers, which are mounted with charcoal points, and adjusted so that they will let as long a spark as the Leyden jar will give pass from one to the other. One of the dischargers is connected by a piece of wet string to the outer coating of the jar, and the other arm is attached to the free chain. If the free chain be brought to the knob of the Leyden jar a spark will pass, and the powder will be exploded; it is best to hold the free end of the chain by the director described at page 14.

Experiment 12.—This is given to explain the last: if we adjust the experiment as before, but instead of the wet string we use the machine chain to connect the coatings of the Leyden jar, the spark will pass, but the powder instead of being exploded will be scattered in all directions. This is generally explained, that the electric spark in passing a bad conductor, the wet string, manifests greater heating powers by the obstruction that it encounters.

Experiment 13.—*To burn a fine iron wire*; we require the universal discharger and a powerful battery. The fine iron wire to be burnt is attached to the two balls of the discharger, which are fixed several inches apart. The chain from one discharger is brought to the outer coating of the Leyden jar, and the chain from the other is fixed to one end of the discharging rod, and the charge of the battery passed.

Experiment 14.—*To burn a gold leaf.* For this we require the universal discharger fitted with charcoal points, and a large Leyden jar or a small battery. The gold is to be cut between two leaves of the book in which it is supplied, to about three-eighths of an inch wide. The charcoal points of the discharger are fixed at about an inch apart. The gold is attached to the points by merely pressing it upon them. The charge is sent through as in the last experiment. The gold disappears with a brilliant flash.

Experiment 15.—*To burn silver leaf:* proceed as in the last experiment, but cut the silver leaf narrower; the flash is green.

Experiment 16.—*To burn Dutch metal leaf:* proceed as in experiment 14, but cut the leaf only an eighth of an inch wide. It will not attach itself to the charcoal points by pressure, but may be tied to them by a piece of fine cotton; when the spark passes, the flash is purple.

Experiment 17.—*To burn tinfoil:* this requires either a very powerful battery, or the foil to be cut very narrow. Attach the foil to the charcoal points with thread, and discharge as before; the light is white.

Experiment 18.—*To show the heating power of the spark, when the substance is not ignited.* Place a rod of wood about two inches long, on the table of the universal discharger; and pass a charge from a battery or large jar several times; the wood will become very hot; if damp, steam will arise, and if the charge be sufficient the wood will fly to pieces. If we wish to ascertain more correctly the heating power of the spark, a longer piece of wood may be taken, and the bulb of a thermometer inserted in a hole sunk in the centre of it. The mercury will be seen to rise with every successive charge passed through it.

Experiment 19.—*To ignite ether.* Warm a tablespoon, and place some ether in it, and set it aside. Take the charged Leyden jar in the left hand, and let one end of the ground chain touch the outer coating. Take the spoon in the right hand and the free end of the ground chain also, holding them so that they touch. If the knob of the jar be now brought over the centre of the spoon, a spark will pass, and the spirit will ignite.

Experiment 20.—*To light a candle with a piece of ice.* The candle for this experiment has to be prepared as follows:—Cut a piece off the top end of a common dip candle, about two inches long, cut the loose cotton off with a pair of scissors, to about half an inch above the tallow, the cotton should be clean; now press a thin wire through the piece of candle from the top end, and let it project some distance below the bottom end, the wire may be concealed. in the cotton. A darning needle or half of a hair-pin will answer well for the wire, particularly if the extreme point be broken off. Place the piece of candle in a metal candlestick, being particular to observe that the wire through the candle touches the socket, after which dip the point of the candle in paraffin oil. Grind a piece of ice to an obtuse point, or procure a short icicle. The candlestick is now to be united by the ground chain to the outer coating of the charged Leyden jar; the free chain attached to the knob of the jar, and also tied by cotton to the icicle. The icicle must be laid on a piece of cloth on a plate, with the point only projecting beyond the edge. If this point be brought over the candle, a spark will pass, and the candle will be ignited. The experiment may be performed in another manner:—An insulated person takes the icicle in his right hand, holding the chain from the machine in his left, and another person brings the prepared candle to him. A spark will proceed from the ice if presented to the wick of the candle, which will ignite it.

Experiment 21.—*To light the gas.* For this experiment take the charged Leyden jar in the hand, with the one end of the ground-chain between the fingers touching the jar. If the free end of the chain be now thrown over the gas arm, the gas turned on, and the knob of the jar brought over the burner, a spark will pass, and the gas will be lighted. The jar supplied with No. 3 machine is sufficient for this experiment.

EXPERIMENTS IN CHANGING THE CHARACTER OF THE ELECTRIC SPARK.—We have already mentioned that the electric spark is a manifestation of the intense heating power of electricity, and that particles of the conductors, between which the spark passes, are really ignited; this gives rise to an amusing series of experiments. By the substitution of different conductors, we have variously coloured sparks. In the most instances, the substances are fixed upon the points of the universal discharger, and the shock passed as in Experiment 14. The following substances are very effective.

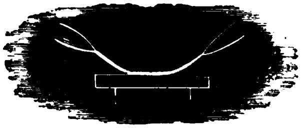
Experiment 22.—*Charcoal points,* fixed in the universal discharger, at a little less distance than the extreme that the spark will pass. The charge from the Leyden jar will produce a yellow spark.

Experiment 23.—Substitute two *ivory balls* in the forceps of the universal discharger. If the current be united, the spark that passes will be crimson; the ivory balls will require to be very small, and at a short distance apart, with a single jar. The experiment is better performed with a battery.

Experiment 24.—*The spark from a silver ball.* Place two balls of copper electro-plated with silver in the universal discharger; let a spark pass from the jar; it will be of a bright green.

Experiment 25.—*The electric spark near the flame of a candle.* Take the charcoal points of the universal discharger, and fix them at double the known distance that the spark will pass. Take a short wax candle ignited, and bring it a little aside, but intermediately between the charcoal points. If a charge be passed as described for previous experiments, the spark will be of great length, of extreme brightness, and curved so as to avoid the flame. This experiment is much more brilliant if performed with a battery.

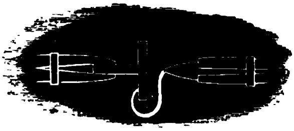
Experiment 26.—Bring the points much nearer than in the last, and let the spark pass just over the wick of the candle, it will now assume a globular form.



Experiment 27.—*The electric spark over water.* Place on the table of the universal discharger a piece of glass, on which is placed a drop or two of water lengthened out

with the finger to about an inch, or more if a battery is to be used. Let the charcoal points be about a quarter of an inch from each end of the streak of water. If a charge be now passed, a spark will run over the surface of the water. By this experiment the spark may be increased to three times its ordinary length, and its brilliancy intensified in the same proportion: it is altogether a beautiful experiment. The spark is supposed to be conducted by the vapour arising from the water.

Experiment 28.—*The spark passing from a point to a globular surface.* In this experiment the pair of forceps of the universal discharger, which is connected by the chain with the machine or inner coating of the jar, is provided with a metal point, and the second pair of forceps carries a metal ball of about three quarters of an inch diameter. After adjustment for distance according to the charge, if a spark or current be passed, the spark from the point to the ball will be divided into numerous branches.

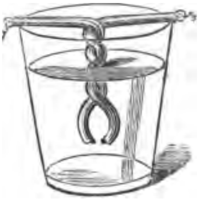


Experiment 29.—*The spark bending to avoid a non-conducting surface.* Let the ball in the last experiment be exchanged for a small disc of vulcanite or gutta-percha cemented upon the end of a piece of stout brass wire, so as to be held in the forceps as the ball was held. If a spark be now passed, it will bend over the edge of the disc, and appear to be repelled by its surface.

Experiment 30.—*The spark on a partially conducting surface.* Let the disc in the last experiment be covered with dew, frost, or steam from a tea kettle, or by wiping it a few times with a wet cloth, so as to cover it with moisture. The spark will pass in all directions in bright veins of light.

Experiment 31.—*The spark over finely divided conductors.* Take a piece of gutta-percha about two inches square, and heat one side until it becomes sticky; press this upon, or sprinkle it over with, fine metal filings. When cold lay it on the table of the universal discharger. If the points be now connected with the edges of the surface, the spark will pass in zigzag lines from point to point. This experiment will be very pretty if filings of different metals are used, as the spark will vary in colour in different parts of its course.

Experiment 32.—*The spark passing a current of air.* Let the spark pass in a current direct from the machine, between the carbon points of the universal discharger. If the spark be now blown crossways with a glass blowpipe, the air will assume a flame-like form.



WATER FUSEE.

Experiment 33.—*To show that the spark will pass under water.* For this experiment we require a piece of gutta-percha insulated wire, of this we construct a small loop and twisted stem, by folding the insulated wire upon itself and twisting it into a kind of cord. If it be held in this form and warmed, it will remain permanent. The loop is then to be cut in two with a pair of scissors, and the two ends separated a little, according to the charge required. If the loop be plunged into water, and one end of the wire be connected by the chain with the outer coating of the charged Leyden jar, and the chain from the other end be brought to the knob by the director, the spark will pass through the water.

Experiment 34.—*The spark through oil.* If the last experiment be repeated with salad oil in place of water, the spark will be of an intense green colour. Most oils would answer except paraffin, or some of the lamp oils which are of a similar nature; these would explode, therefore great caution should be taken with them in experiments of this kind.

Experiment 35.—*To show that the spark really detaches and ignites particles of metal.* Prepare a discharger in the following manner: take two pieces of stout writing paper, three inches by two inches, and paste them over on one side; now cut two pieces of sheet gutta-percha tissue, about three-quarters of an inch square; attach one of them to the centre of one of the pieces of paper, on the pasted side, now cut two slips of tinfoil two inches by half an inch, and round off the ends, place them upon the paper so that the ends touch within a quarter of an inch; place the second piece of gutta-percha tissue over the first, and close the whole with the second piece of pasted paper; after this has dried a short time, a charge or two is to be passed from a battery or jar. If the paper be now torn asunder, small particles of metal will be deposited upon the gutta-percha, sometimes these will be fused, and present a filmy spot; the paper should be slightly moist at the time of the discharge.

MECHANICAL EFFECTS OF THE ELECTRIC DISCHARGE. These are violent expansions which cause laceration, explosions and fractures; the effects are shown upon all non-conductors, when not of sufficient size to resist the effects of the charge.

Experiment 36.—*To perforate a hole through paper or card by electricity.* For this experiment the paper is placed against the outer coating of the charged Leyden jar, and one end of the discharging rod shown at page 12, is placed against it. If the free end of the discharging rod be now brought to the knob of the jar, a spark will pass, and the paper will be perforated with a small hole. The charge from a large Leyden jar will perforate fifty to hundred pages of a book.

Experiment 37.—*To pierce a hole through glass.* For this we require the universal discharger. The glass is required to be very thin for the charge of a single jar or small battery; that used for microscopic objects answers the best. The thin glass requires to be set on edge upon the surface of a piece of stout glass, which may be done with sealing wax. The points of the universal discharger are brought to opposite sides of the glass, and a spark is passed from the jar or battery, which makes a hole through the glass.

ELECTRIC MORTAR.

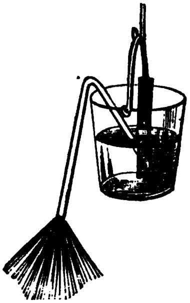
Experiment 38.—*The electric mortar.* This experiment is given to illustrate the expansion of air by electricity. A small mortar is constructed of ivory, having a mouth hollowed out in the form of a deep cup; a boxwood ball is fitted to the cup just tight enough to hold in by its own weight; a small chamber is made in the mortar behind the cup, in which are inserted, at opposite sides, the ends of two wires, so that their points are at about a quarter of an inch apart; one wire is connected with the outer coating of the Leyden jar, and a chain from the inner coating is brought by the point of the discharger over the second wire that forms a kind of touch-hole; and a spark is passed. The spark passing also in the interior of the mortar at the same instant, causes the air to expand with sufficient rapidity for the ball to be thrown from the gun.

Experiment 39.—*The electric charge through plastic substances.* Let two wires be inserted in a lump of soft worked clay, so that the points nearly touch. If a charge be now passed, a large hollow cavity will be blown in the clay near the points.

Experiment 40.—*To destroy gold leaf.* In this experiment we require two pieces of glass about three inches square; two slips of tinfoil are pasted on one piece of glass from opposite edges, so that they reach within half an inch of the centre of the glass, and have therefore their ends at about an inch apart, the slips of foil are left projecting over the edge of the glass on each side, and the paste is thoroughly dried. A piece of gold leaf is now placed in the centre of the glass, so that it touches the two slips of foil, the second glass is then placed over it, and the two glasses are tied together with packthread. If a shock from a large jar be passed through this, the gold will be reduced to fine dust.

Experiment 41.—The three following experiments show the power of electricity in reversing the effects of capillary attraction. The most simple is performed by saturating a piece of sponge with water, and suspending it by a wire from the prime conductor of the machine. Before it is electrified the water will fall drop by drop, but when charged it will pour out in jets, and quickly exhaust the sponge; in the dark the water becomes luminous.

Experiment 42.—*The luminous shower.* We require a bucket the bottom of which is perforated with very fine holes; this is filled with water, and suspended by a silken cord over an empty basin or dish. Before charging the bucket with electricity the water issues from the holes slowly in separate drops; but when the bucket is charged from the chain of the machine, each hole discharges a fine jet, which is perfectly luminous in the dark. It requires a powerful current.



THE ELECTRIC SYPHON.

Experiment 43.—*Funnel and syphon.* This experiment is similar to the last, only that the bucket or funnel has one hole only, and the water is supplied by a glass syphon as it runs out. The water issuing from one hole separates itself by the electrical repulsion of its atoms into a brush-like vaporous form, which is luminous in the dark. In our illustration we have a very simple modification of this experiment. The water is electrified in any vessel, and a glass syphon, first filled with water, is hung over the edge of it. The electrical effects are precisely the same. It requires the power of No. 1 electric disc.

Experiment 44.—*Sand plate.* This experiment shows the arrangement of particles of non-conducting matter under the influence of the electric current. Very fine sand is generally used, but tannic acid being lighter, illustrates the experiment better. With this a piece of glass or vulcanite placed upon the table of the universal discharger is strewn over, and lightly jarred until it spreads equally upon the surface; the points of the discharger are brought down to nearly touch the surface. If the electrical current be passed direct from the machine the particles will arrange themselves in symetrical form, the greater portion leaving the positive point, and accumulating at the back of the negative one.

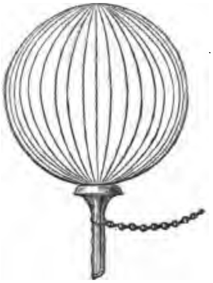
Experiment 45.—*The inclined plane* is an illustration of mechanical motion by electricity against natural gravity. The plane is constructed of two pieces of stretched wire, which are fixed upon an insulated stand in such a manner that they are parallel to each other at about two inches apart, but inclined to the level of the stand about fifteen degrees. An electric whirl which consists of a star of thin wire, each point of which is turned at right angles to its radiation in the direction of the plane of its surface, is mounted in the centre of a wire axle and placed on the plane.

Charged with electricity through one of the fixed wires, the whirl will roll gradually upwards.

EXPERIMENTS WHICH SHOW THAT OBJECTS OR PARTICLES OF OBJECTS CHARGED WITH LIKE ELECTRICITY ARE REPELLED FROM EACH OTHER.

Experiment 46.—*The head of hair.* For this experiment, the metal wire on which the head is fixed is inserted in the prime conductor of the machine. The machine is then turned; should the hair, through its hydrometrical state, not rise quickly, the hand may be held a short distance over the head, and the hair will be quickly attracted to it.

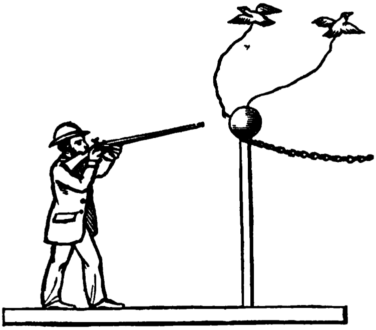
Experiment 47.—A pretty variation of the above is to have, instead of the head of hair, a metal ball similar to the prime conductor to our electrical disc, placed on a wire stem, and long strips of different coloured tissue paper attached to the ball, so that each strip touches the metal. If this be charged with electricity similarly to the last experiment, the papers will float about in a most fantastic manner.



Experiment 48.—*The electrical balloon.* It is obvious that the two previous experiments show the repulsive power of electricity, the hair or papers being charged are only retained in contact with the conductor by the strength of the cement attaching them by one end. The electrical balloon is a variation of this experiment in having both ends attached, and answers very well with paper slips as in the last experiment. As we have arranged it, it consists of ball and stem, as before; attached to the top of the ball are a quantity of silk cords of different colours; these are united at equal distances from the ball to a very small piece of pith. When the experiment is charged with electricity, the cords expand as in the illustration, and form a pretty experiment. The top of the balloon should be raised by the hand, as in the head experiment, until the cords are fairly expanded. This experiment requires a powerful electric current.

Experiment 49.—*Wax threads.* Fasten a piece of sealing wax to a wire, and insert the wire in the hole of the prime conductor. Soften the sealing wax by the flame of a candle, and work the machine. Fine silky fibres of wax will be thrown off, which may be collected upon paper. By afterwards warming the paper, the fibres will attach themselves firmly to it. The fibres of wax are thrown off by the repulsion of their own electrified particles, the wax when melted becoming a conductor.

Experiment 50.—*The camphor plant.* Place a piece of camphor in a warm spoon, which may be insulated by tying it to the foot of a wine glass; connect the spoon with the chain of the machine, and ignite the camphor. When the current of electricity passes, the camphor will shoot out in branches like a growing plant.

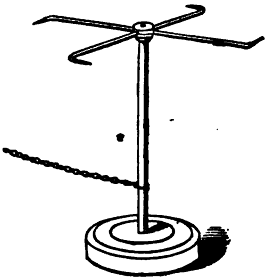


Experiment 51.—*The sportsman and birds.* This consists of a pair of birds which are made of pith and feathers, and are attached to an insulated knob or to the knob of the Leyden jar by silk threads; and the sportsman, which is constructed as a conductor to take the electricity from the knob to the ground. Our experiment is performed by the intervention of the Leyden jar; the chain from the machine is connected with the knob of the jar, and the free chain from the jar to the insulated knob on the stand. When the machine is worked the birds charge with electricity, and are repelled from the insulated knob. The sportsman being a conductor and connected to the ground, is brought gradually towards

the knob; when he is sufficiently near, a spark passes between the knob and the point of his gun with a sharp noise; thus taking the charge from the birds, they instantly fall.

EXPERIMENTS WHICH SHOW THAT PARTICLES OF AIR, WHEN CHARGED WITH LIKE ELECTRICITY, ARE REPELLED AS OTHER LIGHT BODIES ARE.

Experiment 52.—*To blow a candle out by electricity.* This experiment is an illustration of the repulsive power of electricity acting upon the atmosphere. It is found that electricity will always pass off by preference from a pointed conductor. In passing off into the atmosphere from a point, the particles of air near the point become charged, and are repelled just as other light bodies are under similar circumstances, as we see in the head of hair. The atmosphere being repelled principally from the point, it forms a current which will blow a candle, or, if strong enough, blow it quite out. All we need for this experiment is the chain led from the machine, and a sharp-pointed strong pin tied to it with a piece of thread, to form a blower.



ELECTRIC WHIRL.

Experiment 53.—*The electrical whirl.* This is founded on the same principle as the last experiment.

It consists of a boss of metal from which four or more light arms extend a few inches. The arms are pointed, and the points are turned at right angles to the arms. The centre boss has a small hole through it, which fits on a pin, the whole being fixed on a stand, which it is necessary to insulate; this may be conveniently done by standing it upon a dry dinner plate, in default of an insulating stool. When the chain from the machine is connected, the electricity passing off the points causes the whirl to spin round; in the dark a luminous brush is seen from each point.

ELECTRIC WINDMILL.

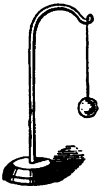
Experiment 54.—*The windmill.* This is a modification of the whirl experiment, in which the whirl placed vertically and disguised by paper sails, is centred upon an insulated wooden mill. The electricity passing into the air from the points, causes the sails to turn with equal motion, the chain being connected directly from the machine to the mill.

Experiment 55.—*The electric fly-wheel.* This is another modification of the whirl, and consists of a wheel cut out of very thin sheet copper or brass, centred on an axis with two points, and supported on a stand, which requires insulation. The edge of the fly-wheel is cut in the form of very elongated saw teeth, from the points of which the electricity driving the particles of air causes it to move with rapid motion, when charged by the chain direct from the machine.

Experiment 56.—*The electric engine.* In this the fly-wheel described above has a cranked axle, and is caused to work a small imitation steam-engine. The experiment is amusing, in that observers look to the piston for the source of motion.

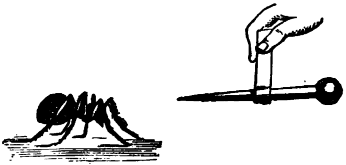
Experiment 57.—*The electrical orrery or planetarium.* This experiment consists of three balls; one large to represent the sun, a much smaller one to represent the earth, and a very small one for the moon. The image of the earth and moon form the two ends of a light rod, which is centred so that they will balance and swing round on a point, which will be, from the difference of size, very near the *earth.* The ball to represent the sun is also placed on the end of a rod, the other end of which is turned up to form a centre for the two balls which represent the earth and moon. The whole apparatus is balanced and centred so that it will turn freely on a point, which from the difference of weight of the parts, comes very near the sun. From the moon a point is projected horizontally, which causes it by the passing of the current to move round the earth; and two similar points on the rod connected with the sun cause the earth and moon to revolve apparently round the sun. Really the moon and earth, and earth and sun respectively revolve in a circle in equal times; but the centre being in each instance near the larger body, they do not appear to do so.

EXPERIMENTS WHICH SHOW ALTERNATE ATTRACTION AND REPULSION.

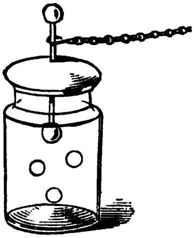


INSULATED PITH-BALL STAND.

Experiment 58.— *The insulated pith-ball stand.* This apparatus is the most convenient to show electrical attraction and subsequent repulsion in its simplest form. It is used also for other experiments which we will touch upon under another heading. Although we shall not need the electric disc to attract and repel the pith ball for this experiment, it explains the electrical law by which other experiments that do require it act. If we rub a stick of sealing-wax or a glass rod until it is warm, on a piece of woollen cloth, and apply it to a pith ball suspended by a fine piece of silk, we shall find that the ball is attracted to the rubbed surface until it touches it. After it has remained in contact a second or two, the same surface repels it, and will continue to do so for a considerable time; but if we apply the finger or any other object to the ball, it will be attracted to this until it touches, after which it will be again attracted and repelled by the first excited surface. If we let the ball hang between our finger or any other conductor and the surface of the rubbed wax or glass, the ball will continue to go backwards and forwards from one to the other. In this experiment the finger takes the electricity from the ball and conveys it to the earth, and makes it free to be again acted upon by the excited surface.



Experiment 59.—*The electrical spider.* This experiment shows the effect of a body retaining electricity so that another body does not become charged without touching, whereas electricity thrown off a point is sufficient to charge a body at a distance. The electrical spider consists of a piece of pith painted like a spider, and supported on horse-hair legs, and placed upon a piece of glass. A piece of wire, having a ball at one end and a sharp point at the other, with insulated handle to hold it, is connected with the chain of the machine, and charged. When the ball is presented to the spider it is attracted; but when the point is presented it is repelled. To render the experiment more amusing, the ball is sometimes painted to imitate a fly.



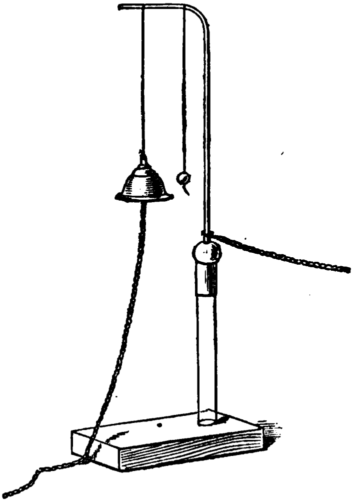
PITH-BALL STAND.

Experiment 60.—*The pith-ball stand.* In this experiment the pith balls are acted upon by attraction and repulsion, as in 58, but the balls being enclosed the action is continuous. The apparatus consists of a glass jar, having a wooden cap fitted upon the top lined with tinfoil. The bottom of the jar is also coated with foil inside and out, and the two coatings are connected together by a wire inserted in the glass. Through the lid of the jar a metal rod extends a distance which is adjustable to accord with the power of the machine: this rod has a knob at either end. Several pith balls are placed in the jar. The chain from the machine is connected directly with the rod in the cap of the jar. When the machine is worked the balls fly about in all directions, the knob attracting and repelling, and the lower surface carrying the electricity off to the earth so that the balls may be again attracted.

Experiment 61.—*Snowballing.* This is a modification of the last. The jar is placed horizontally, and a figure is fixed near either end, one to connect with the machine, and one with the ground. Several pith balls are thrown loosely in the jar. The attraction and repulsion of the loose balls cause the figures to appear to pelt each other.

Experiment 62.—*The electric ring.* A metal ring is placed upon a disc of glass, the disc is supported by a metal rod in the centre, which passes through the glass and conducts to the earth. Several light blown glass balls are laid on the disc between the ring and the centre. The chain from the machine is connected with the ring. When electricity is excited the ring alternately attracts and repels the balls, and keeps them in continual motion. The whole is luminous in the dark.

Experiment 63.—*The scullers.* For this experiment a boat with two boatmen is fixed upon a piece of glass, coloured on the under side to imitate water. The figures have an axis at the seat, in about the centre of their gravity. They hold a pair of oars which are balanced on the sides of the boat. Two small knobs in the bottom of the boat, one connected with the machine, and the other with the earth, alternately attract and repel the lower portion of the figures, giving them a rocking motion, also working the oars.



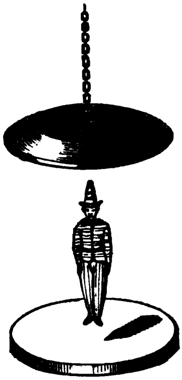
ELECTRIC BELL.

Experiment 64.—*The electric bell.* This experiment illustrates the power of attraction and repulsion as in experiment 58; but instead of a light substance (the pith ball) we have a metal ball insulated by hanging it on a thread of silk. A small bell is also insulated in a similar manner, and both are hung at a short distance apart, upon a small metal crane, which also requires to be insulated from the ground by a glass stand. A chain from the centre of the bell is conveyed to some object in connection with the ground, and the chain from the machine is connected with the metal crane on which the bell and ball are suspended. When the machine is worked the side of the crane attracts and repels the ball, and causes it to strike the bell rapidly. The ball and bell sometimes require a little adjustment for striking distance. When the ball is in motion it is necessary to work the machine very slowly, or the electricity will pass in sparks, instead of by striking contact.

Experiment 65.—A variation of the above experiment is made by fixing a second bell on the stem of the crane, or by fixing one bell on a centre stem, and three or four other bells, each with suspended balls, surrounding it. The effect of either of these plans is of course increase of sound. The equivalent arrangement is often fixed on the top of a Leyden jar.

Experiment 66.—*The electric chime.* This apparatus consists of eight bells made to musical notes, and arranged in a circle upon a horizontal stand. In the centre of the stand a glass rod is fixed, which supports an electric whirl described in experiment 53, at about six inches above the bells. The whirl carries with its motion a metal ball suspended by a silk thread, and a second metal ball nearer the centre, fixed upon a piece of wire. When the machine is worked, the ball upon the wire, taking the electricity, attracts and afterwards repels the suspended ball, which causes it to strike one of the bells; at the same time the whirl carries the ball along to another, so that each bell is struck in succession.

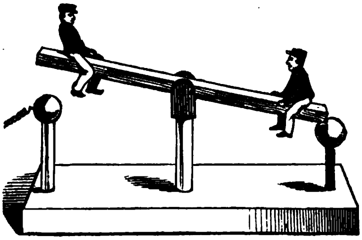
Experiment 67.—*The Æolian chime.* In this, instead of bells we have plates of metal, such as are used for the harmonicon; these are suspended vertically by silk cords, at about an inch or two apart; a metal ball is also suspended in each space between the plates. The first plate of the series is conducted to the machine, the last to the earth. When the electric current passes, the balls take a swinging motion and chime upon the plates, but seldom in regular succession, therefore it is best to have the plate notes for one chord only, in two or more octaves.



THE IMAGE PLATE

Experiment 68.—*The image plate.* This experiment consists of two metal plates fixed upon a stand horizontally, at about two inches apart. The upper plate is insulated by being suspended by a silk cord; the lower plate is connected with the ground; a comical figure or figures are placed between the plates. The chain from the machine being connected with the upper plate, the electricity as it passes will alternately attract and repel the figures, which will cause them to dance about most amusingly, according to the rate that the machine is turned.

Experiment 69.—*Franklin's fly wheel.* A small wheel having glass spokes is fixed horizontally, so as to balance upon a point. The glass spokes are carried through the rim of the wheel. On the end of each spoke is fixed a metal ball; the whole is placed upon a stand between two balls, one insulated, and one connected with the ground. The insulated ball being connected with the machine, the balls on the fly wheel, after it has been started one turn, will be alternately attracted and repelled, so that the wheel will fly round rapidly and continuously.



ELECTRIC SEE-SAW.

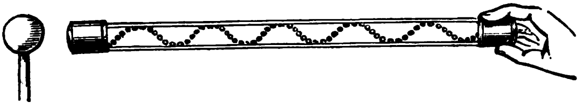
Experiment 70.—*The see-saw.* For this we require two small figures balanced as upon the beam of a scale, the centre support of which requires to be insulated by a glass rod. A metal ball is fixed under each figure, one ball insulated by a glass rod, and the other connected with the ground. The chain from the machine being fixed to the insulated ball, the nearest figure is attracted and afterwards repelled, until the opposite figure touches the groundwork and therefore discharges the electricity, which allows the first figure to be again attracted and repelled as before. The experiment forms an excellent illustration of attraction and repulsion.

Experiment 71.—*The swing* has the same arrangement as the last, only that in place of the see-saw a small figure is suspended by two silk cords to form a swing. The principle is the same as the bell experiment.

VARIOUS LUMINOUS EFFECTS OF THE ELECTRIC SPARK AND CURRENT, WHICH PARTICULARLY REQUIRE TO BE PERFORMED IN THE DARK.

Experiment 72.—*The star and brush.* This experiment is a very simple one, but it is instructive as illustrating a phenomenon of electricity which is in itself very curious. That is, that electricity flying off from a point assumes the form of a luminous brush; but upon collecting or entering a point, it assumes the form of a star. The experiment may be easily performed by tying a large household pin to the end of the machine chain, and insulating it by attaching it to a stick of sealing wax. If a person hold another pin, and bring the point near to the one affixed to the chain, a current will pass, leaving the pin on the chain as a brush, and being received on the pin held in the hand as a star. This experiment is performed more effectively by fixing points in the clips of the universal discharger, already described, and allowing the current of a No. 1 or 2 machine to pass.

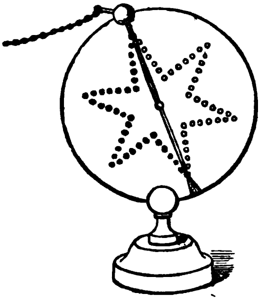
Experiment 73.—*The diamond jar.* A very large class of luminous experiments are produced by breaking the conductor by various means, so as to exhibit the electric spark at all the breaks. The diamond jar is undoubtedly the best of these, and at the same time the most tedious to construct. It is really a Leyden jar; but the foil instead of being attached in a broad sheet is cut up into small diamond-shaped pieces, each with a hole in the centre. These are cemented entirely over the inside and outside of the jar, each diamond being fixed with great precision so that every angle shall be a short distance from the contiguous angle of the next diamond, also that every angle on the inside shall come in the place of the hole in the centre of the diamond on the outside; the jar is covered with a cap, and a ball, rod, and chain is fixed into it as in the Leyden jar. The experiment is performed by charging the jar, and afterwards discharging it with the discharging rod, the effect of which is that the jar is illuminated all over with brilliant sparks of electric light.



ELECTRIC DOT TUBE.

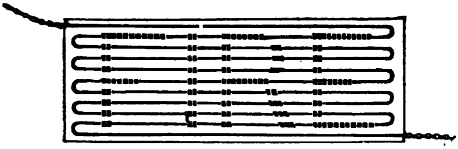
Experiment 74.—*The dot tube.* This consists of a tube of glass, with a metal cap at each end. Along the inside of the tube is cemented a series of metal dots separated a short distance from each other, and arranged generally in spiral form, so that the last dot at each end of the tube touches the metal cap. The electricity is passed through the tube, either by holding it in the hand by one end, and applying the other a short distance from the Leyden jar, while the machine is continuously turned, or by hanging the tube in the insulating and conducting stand. The luminous effect is a spiral of brilliant sparks; this tube requires No. 1 or 2 machine to work it; the ground chain may be held in the hand, so that it will touch the outer coating of the jar, when used as first directed.

Experiment 75.—*The star plate.* This experiment is upon the same principle as the last; but the dots are affixed to a circular disc of glass, and placed on a stand. The knob of the Leyden jar in this experiment has to be placed about a quarter of an inch from the knob at the top edge of the plate, and the electricity conducted from the under side of the stand to some conductor in connection with the ground. The luminous effect is a star-shaped figure. This experiment is often varied by having various objects delineated on the glass by dots, as a house, animals, etc.



Experiment 76.—*The electric spectrum.* This is only a simple modification of the last; it consists of three or more pieces of coloured glass fixed in a frame, generally arranged as in the spectrum—red, yellow, and blue. A series of dots as in the star plate are arranged in serpentine form upon the back surface of the glass. When the current is passed from the Leyden jar, as explained for the star plate, the luminous effect is a line of lights which appears to change in colour as it passes behind the glass.

Experiment 77.—*Luminous book.* Procure a book having the cover and back richly gilt; take the ground chain in the hand in which the book is held, and let the other end of the chain touch the outer coating of the charged Leyden jar. Now bring a portion of the gilding to the knob of the jar; the electricity will flash along the gilding in streams of green light. If another person work the machine the jar may be continually filled, so as to repeat the experiment at short intervals.



ELECTRIC WORD PLATE.

Experiment 78.—*Word plates.* These are constructed upon the same principle as the star plates, and only vary in the system of conducting the electricity, which is effected by continuous narrow bands of foil attached at equal distances longitudinally on the slips of glass, each pair being connected at alternate ends; the words are formed by the bands of foil being detached only where the lines of the letters occur. Word plates require a strong current, and the spark to be taken from a large Leyden jar; No. 1 machine only performs this experiment effectively.

Experiment 79.—*Electric designs on card.* The last experiment may be performed by placing the lines on paper or card, but the effect is not so good as upon glass. A more effective way is to have a sheet of black pasteboard, which should be well varnished back and front, and to make the words in dots of tinfoil, pasted on at short distances apart, following the outlines of writing letters. Where there are any breaks between the letters or parts of them, a long slip of foil must be fixed to convey the electricity from point to point. The tinfoil may be painted the same colour as the paper, and no words nor designs will be seen on the surface until the ends are connected with the Leyden jar and a charge is passed.

Experiment 80.—*Tin tack conductors.* A very simple way of making dot experiments is to obtain a piece of dry wood, and draw out upon it a word or design, the lines of which must be followed continuously by tin tacks driven in at short distances from each other, and to an equal depth, so that the heads form a level plane. The simplest way of proceeding is to first cover the wood with paper attached with paste, and then to set out the distances for the tacks with a pair of compasses; a small hole may be made in the compass marks with a pointed awl or a fork, which will insure equal distances. If this experiment is executed on a large scale, large-headed wrought iron carpet tacks should be used, or cheap drawing pins will answer very well. The surface of the paper should be varnished.

Experiment 81.—*The sparkle tube.* This consists of a tube of glass, capped at each end, and containing a rusty iron chain. The electricity is passed through it similarly to the dot tube. The luminous effect is a series of flashing lines of light, very effective.

Experiment 82.—*Luminous chain.* If the chain in the last experiment, instead of being placed in the tube, be hung from ball to ball of the insulating and conducting stand, it will appear very luminous, although less so than in the tube; but if several lengths of coloured glass tube be strung over it it will thus form a very pretty experiment.

Experiment 83.—*The bead chain* is constructed of a series of beads threaded upon silk, alternately one large of metal, and one small of glass. The glass beads are of various bright colours. The hole in the glass bead is of sufficient size to let the spark pass through it from metal bead to bead. It is fixed in the insulating and conducting stand, and sparks passed through it from the Leyden jar, the knob of which should be placed at about a quarter of an inch from the insulated knob of the stand. The luminous effect is a chain of sparks of various colours.

Experiment 84.—*Luminous eggs.* A single egg may be taken, and the spark passed through it; it will be luminated by the spark, and will also appear luminous in the dark afterwards. Or a current may be passed, and it will become very luminous if the current is of sufficient strength. The manner this experiment is generally shown is to have a small stand on which the egg or eggs may be fixed, by holes in glass sufficiently large to admit them to stand firmly, at a proper distance from the balls of the discharger.

Experiment 85.—*Luminous eggs.* This experiment used to be performed in another manner at the Polytechnic Institution some years since. A chain of hollow wax imitation eggs of various colours was suspended by a wire conductor, which was broken in the centre of each wax egg, so that a spark passed and illuminated the whole chain.

Experiment 86.—*Luminous fruit.* An orange for this is particularly effective. Attach one side to the ground chain by a tin tack pressed into the eye of the orange, lead the chain off to the outer coating of the Leyden jar or battery; if the chain from the knob of the charged jar be brought by the discharger to the opposite end of the orange, a spark will pass, which will render the orange luminous.

Experiment 87.—*Luminous dish of fruit.* Pass the current direct from the machine through the several fruits insulated separately, and afterwards take the whole on a dish into the dark; if the weather be dry it will appear sufficiently phosphorescent to distinguish each kind of fruit.

Experiment 88.—*Luminous fish.* If the chain direct from the machine be tied to the tail of a fish (a sprat or herring answers very well) by a piece of cotton, and the finger of an assistant be placed in the mouth, when the machine is worked the fish will become luminous.

Experiment 89.—*Phosphorescent tube.* Take a small glass tube, fill it tightly with dry sulphide of calcium, and stop each end with a cork covered with tin foil; pass the electric current through it direct from the machine. Afterwards if it is removed into the dark it will be luminous for a considerable time. If the air is partially exhausted in a tube of this class, the tube may be made larger and longer, and the experiment will answer better.

Experiment 90.—*The storm picture.* Take a print, a water-colour drawing or a print mounted on card representing a storm; draw in lightly with pencil a flash of forked lightning where required for effect, and pierce the two ends of the flash through the card with the point of a penknife; insert a slip of tinfoil from the back of each hole so that it comes through to the front, and paste the remainder of the slip along the back of the picture to the extreme edge, one slip going to the right and the other to the left; turn the ends of the foil down a little on the front, and cut them off; place small dots of foil at distances along where the flash is intended to appear; the foil must now be coloured over the same tint as the picture, so that it is not observed. If one end of the foil be connected with the outer coating of the jar by the ground chain, the other foil with the knob, and a charge passed, the flash of lightning will appear on the picture.

Experiment 91.—The last experiment may be performed with less trouble if a large Leyden jar or small battery be used. The tinfoil may then be pasted as before on the back of the picture, which must be on paper only, and the flash be formed by making a streak from point to point of the foil with thick gum-water, and sprinkling this over with brass filings; a piece of paper may be pasted over the whole to protect it. The electric light will appear quite bright through the thickness of the paper picture as though it were on the surface.

Experiment 92.—*The electrical battle.* For this experiment a picture representing a battle scene is taken. One cut from an old *Illustrated London News* answers very nicely. A strip of tin-foil is pasted along the edge of one side at the back. The picture is then placed against a window so that the position of all the figures upon it may be seen from the back, where the tinfoil is to be pasted in the following manner: a very narrow slip of foil is led from one of the guns held by a soldier to the foil on the edge, a little break is made at the end of the gun, and the narrow foil is led on to another gun, and so on until a sufficient number of soldiers to fire at once is obtained; the strip of foil is then led off to the opposite edge of the paper to that on which the slip was first placed, and the end turned over a short distance on the face of the picture. Another slip is led off from the first slip up the edge to another group of soldiers and, after a break is made at the ends of the guns, this is also led as before to the opposite edge of the paper, and the same way for another or more groups as may be thought effective, the slip being in each instance carried off to a separate place on the edge of the picture, and not crossing each other in any part, nor being so close that the electric spark will pass at any place except at the ends of the guns. When the whole is arranged, the picture may be mounted on cardboard. To show the experiment, the slip of tin-foil along the first edge has to be connected with a long ground chain from the Leyden jar, the charged jar is brought alternately to the separate ends of foil, by the director, and each time a spark passes a group will appear to fire. The jar is better held in the hand with one end of the ground chain; and the machine connected and worked by an assistant, so that the jar is quickly charged sufficiently for a spark.

Experiment 93.—*Sea fight.* For this proceed as in the last experiment, except that before the foil is pasted on the back of the picture that represents the fight, paste over the mouth of each gun first a piece of dark crimson glass about half an inch square, and then place the ends of the foil upon this, the light from the guns will appear red. Many other similar experiments may be performed with pictures, as the sparks from a steam engine or boat, shooting-stars, fire fountains, illuminations, the blacksmith, and other *light* effects, which may be easily effected with metal filings and slips and dots of foil and pieces of gelatine or glass placed behind suitable pictures.

EXPERIMENTS SHOWING THE LUMINOUS EFFECTS OF ELECTRICITY PASSING THROUGH VARIOUS GASES AND RAREFIED AIR. Partial vacuum experiments which have of late been so very popular, have been conducted with dynamical electricity, upon which we do not intend to touch, but there is no reason that statical electricity, of which we treat, should not be used with equal effect. Our No. 3 machine will illuminate a small rare-air tube (vacuum tube, as it is called), as effectually as a small voltaic battery with intensity coil, that would cost three times the price. Our No. 1 machine will illuminate a tube as effectively as a powerful battery, and we have not the expense or danger of chemicals. Vacuum luminous experiments are very beautiful, and if elaborate are very expensive. It happens fortunately that we can have the most of them executed for us in a simple form, equally beautiful and illustrative on a small scale, at very moderate cost. We shall be obliged, however, for ex-

planation to describe the following instrument, to explain the electrical effects upon which vacuum tubes are constructed.

THE LUMINOUS GLOBE. This instrument consists of a globe of glass, having two opposite necks, each fitted with a brass cap and collar, into which a conductor terminating with a brass ball is fixed so that the two opposite balls rest each at the same distance in the globe. One conductor, exterior to the globe, terminates with a brass ball; the other with a stop-cock with a fitting that will screw to an air-pump, to exhaust the air from the interior when required.

Experiment 94.—*Passage of Electricity through a partial vacuum.* Screw the luminous globe to an air-pump, and exhaust the air as much as possible; turn off the stop-cock and remove the globe. If now electricity be passed by connecting the upper knob with the chain from the machine, and the lower one with the ground, it will fill the globe with a purple light, which will appear to flow from the upper ball as from a fountain.

Experiment 95.—*Attraction of the vacuum flame.* If the finger or any other conductor be brought to the side of the globe, while performing the last experiment, the electric flame will be attracted from its course towards it through the glass globe.

ELECTRICITY THROUGH VARIOUS GASES. For these experiments we fill the globe described with water or mercury, according to whether we wish the gas dry or moist, and force the gas to be experimented upon through the stop-cock while it is under the water or mercury, until the liquid is expelled. If the gas is only wanted in a rarefied state, it is quite sufficient to exhaust the globe, and screw it upon the bottle containing the gas to be examined.

Experiment 96.—*Electricity through hydrogen.* The conducting knobs in the globe should be adjustable for this experiment, and be brought within a short distance of each other, so that a spark will pass, equal to the power of the jar or battery at hand. The globe being filled with hydrogen gas, a charge passed from the battery will be of a fine crimson colour.

Experiment 97.—*Electricity through rarefied hydrogen.* Take the globe from the last experiment, and draw the conducting knobs nearly as far asunder as the globe will admit of, exhaust the gas as far as possible with the air-pump, so as to form what is termed a hydrogen vacuum. If a charge be now passed, the globe will be illuminated with white light, but the effect is much better if one conductor of the globe be attached to the chain of the machine, and the other be held in the hand or otherwise conducted to the earth while the machine is worked, so that a current may pass through the rarefied gas.

Experiment 98.—*Electric charge through nitrogen.* Proceed as in experiment 96, but have the globe filled with nitrogen; the spark will be an intense blue, and very brilliant.

Experiment 99.—*Electricity through rarefied nitrogen.* Rarefy the nitrogen by the air-pump as in experiment 97. The current of electricity will now be a rose colour with a slight tint of orange.

Experiment 100.—*Electric charge through carbonic acid gas.* Proceed as in experiment 96; the spark will be pale green. If the tube be exhausted as in the other experiments, the light will still be pale green. This gas does not change by rarefaction, only to become paler.

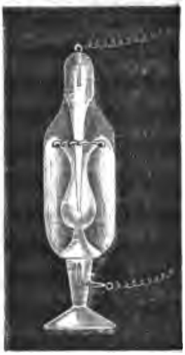
Experiment 101.—*Electric charge through coal gas.*

This being a mixed gas, the colour of the spark varies according to the quality, for which there is no doubt that the electric charge would form a good and simple test: for the colour varies in almost every instance, with one gas it is red, with another green; sometimes it is bright and dense, sometimes dull and expanded.

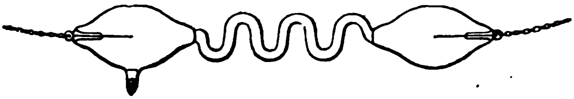
Other gases generally produce white sparks; the exhausted flame is also white or with slight tint of colour. It is upon the principle of the variation of colour in nearly exhausted gases, that the very popular vacuum tubes, as they are termed, are constructed. These tubes are made of various fanciful forms by the glass blower, enclosing a partial vacuum of air or gas, as taste or design may direct. It is not by the gases and forms alone that endless variety may be obtained; he also calls in the aid of mineral colours in the glass, which act by a principle assumed to be *fluorescence,* by which many minerals that give very little tint to the glass, acquire great brilliancy when the electrical vacuum light is seen through them. The substance most particularly effective for colouring the glass is the oxide of uranium; this makes the glass a pale greenish yellow, but the electric light appears through it of a brilliant emerald green.

Experiment 102.—*Vacuum tube.* Attach the tube illustrated above, by one of the fine platinum loops at the end, to the chain of the machine; hold the other end against the finger. If the machine be now

worked, the tube will appear luminous in the dark; the colour of the light will be in accordance with the rarefied gas that the tube contains.

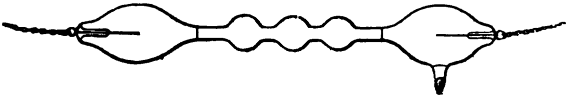


Experiment 103.—*The fountain tube, sometimes called Gassiot's cascade.* In this beautiful experiment there is an inner tube constructed in the form of a vase; the electricity from the point to which the chain is attached is conducted by a diminishing glass tube to nearly the bottom of the vase; the electricity on passing to the lower conductor appears to fill the vase, and flow like liquid fire over its edge.



Experiment 104.—*Spiral and zigzag tubes.* These are constructed of various devices. The platinum points are generally fixed in an air vacuum globe, and the intervening spiral is generally made of glass, stained with oxide of uranium. When the current is passed

from the chain of the machine, the globe fills with purple light, and the spiral with intense emerald green.



Experiment 105.—*Bulb tubes.* These tubes contain exhausted air of vacuum, they are made of many devices. The effect of the passing of the electric current is intense brightness in the fine stems shading off to purple in the bulbs.

Experiment 106.—*Compound tubes.* These tubes are generally made so that the electricity shall pass in very fine glass tubes which are bent into fanciful devices, spirals, volutes, etc. The tubes generally contain exhausted carbonic acid gas, which gives a powerful light; the whole design is placed in a large tube or bottle, which is sealed to the device by the glass blower. The outer tube may be filled with any liquid which will entirely surround the device. If the electricity be passed through the inner tube before the outer tube is filled, the device will appear in white light; but if the outer tube be filled with a saturate solution of sulphate of quinine, which is quite colourless, the light will appear an intense ethereal blue.

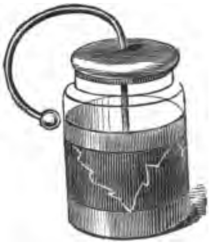
Experiment 107.—*Word tubes.* These are constructed similarly to the last, but the fine tube is blown to form words, as, 'Good night,' etc.

Experiment 108.—*The ball tube.* This tube is prepared with a cap at each end, it should be long but of small diameter. Small dots of tin foil are fixed at about half an inch apart, and the tube is partially exhausted of air. When a spark is passed, it appears filled with luminous beads.

Experiment 109.—*The serpentine tube.* This tube is similar to the last, but small dots are fixed at alternate sides; the electricity appears to move along in serpentine form. The two last experiments are quite new.

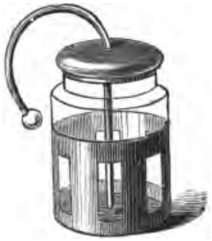
Experiment 110.—*The perfect vacuum tube.* In this tube, the points of the platinum nearly touch, but the resistance offered by the absolute vacuum is so great that the electricity will not pass at the points, but will rather pass over the entire exterior surface of the glass.

EXPERIMENTS WHICH ILLUSTRATE THE THEORY. ELECTRICITY AS THE ACTIVE AGENT IN VARIOUS ATMOSPHERIC PHENOMENA.

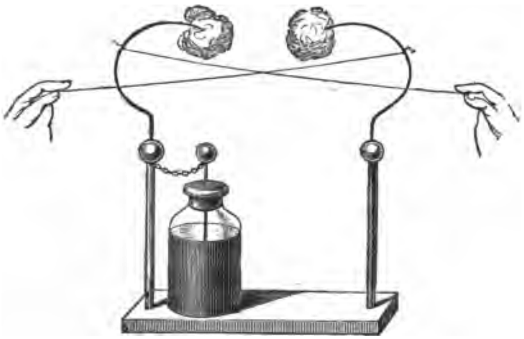


Experiment 111.—*The lightning jar.* This is a very illustrative experiment of what is presumed to take place in the atmosphere to produce the effect of forked lightning, particles of metal being used as a conductor to carry off the electricity to the earth, in the same manner as the separate drop of water or vapour would in the atmosphere. The experiment consists of a Leyden jar, the outer coating of which is replaced by detached metal filings. The conductor from the inner coating is bent over, so that when the interior coating is charged, it discharges itself to the metal filings, which convey the electricity to the ground. As the electricity

passes from particle to particle of the metal in zigzag course,an exact imitation of forked lightning is produced.



Experiment 112.—*The sheet lightning jar.* This experiment, as the last, is a Leyden jar, but there is no chain attached to the bottom of the conductor to conduct the electricity to the inner coating, and a series of windows are cut out of the foil, so as to show the *light* effects inside the jar. The conductor of the jar being charged with electricity from the machine, and there being no connection with the inner coating except by the charged atmosphere in the jar; the spark passes, when sufficient degree of tension is produced, in a sheet-flash, which illuminates the whole interior of the jar.



Experiment 113.—*The thunder clouds.* For this ex-

periment a Leyden jar is constructed with a second inner rod from near one edge of the cover, the rod is carried up a considerable distance, and bent outwards away from the jar; it terminates with a small ball covered with a large tuft of cotton to imitate a cloud. Another similar bent rod, with a tuft of wool also, is carried up from a stand, covered with tinfoil, on which the Leyden jar is placed. A silk cord is attached to each rod. If the Leyden jar be now fully charged, and the clouds be drawn nearly together, a flash with report will pass between the clouds, which will imitate sheet lightning. The experiment also imitates the phenomenon of the meeting of clouds charged with electricity in another manner. It will be observed, as the cotton clouds are charged with electricity, that they extend the cotton fibres in all directions, upwards particularly, but when the flash passes, the cotton condenses again to its usual bulk, as the vapour of the cloud when not expanded and sustained by the repulsive power of electricity, acting upon its own particles and the earth, is suddenly condensed by the electric discharge into drops of water which afterwards fall to the earth in rain.

Experiment 114.—*Cloud and conductor*. This illustrates the value of lightning conductors. The experiment consists of a small house which has the representation of a lightning conductor attached to it, a separated insulated stand has a bar of conducting material balanced horizontally upon it; at one end of the bar is a tuft of light cotton wool, this stand is connected with the inner coating of a large Leyden jar or battery. When the wool which is to represent a cloud is brought near the conductor fixed to the house, a flash and report passes, which is conveyed to the earth by the conductor. This experiment is sometimes varied by having the conductor detached inside the house, and a small pan of gunpowder or other combustible placed in the detached part; when the electricity strikes it, the powder is exploded and the house is blown to pieces, illustrating the danger of metal connected with the roof of a building containing combustible substances, without metal conductors to the earth. The house for this last experiment has to be constructed in pieces, which a small charge of powder will blow down.

Experiment 115.—*The obelisk.* This shows the effect of lightning, that is of *electricity,* acting upon conducting and non-conducting erections. The obelisk is constructed of a long conical form, and rests on a cubical base; a line of metal conductor is inserted down one side of the obelisk, and a similar line in the base meets it, and is connected with the first on its under surface to convey the electricity to the earth. Between the obelisk and base is a small hollow, which forms an air chamber; this is also connected with the conductor. When the conductor on the obelisk meets that on the base, and a charge of the battery is passed, the electricity passes down the conductors, and no effect is observed; but if the obelisk is turned to another angle upon the base, so that the conductors do not meet, and the electricity to pass to the earth has to cross the non-conducting air chamber to reach the lower conductor, the effect is, that the air in the chamber is expanded with such force that the obelisk is thrown down. This experiment is very instructive of the manner in which buildings are injured by lightning.

Experiment 116.—*The fire house.* For this we require a model house made of metal and painted with mineral colours that will not be effected by heat; a conductor is led from the chimney of the house to the interior, and meets another conductor within about a quarter of an inch. The roof of the house lifts off with the upper conductor. To show the experiment, a tuft of cotton saturated with ether is placed on the lower conductor when the roof is put on, and a charge of the jar passed, the house bursts into flames which issue from the windows and chimney. This experiment should be stood on a sheet of tin.

Experiment 117.—*The electrical flask.* This is constructed of a Florence flask with brass cap and valve, so that it can be partially exhausted of air, so as to represent the rarefied air of great altitudes; a ball conductor is screwed on the top of the cap, and a point projects from the cap some distance into the flask. The air being partially exhausted, charges of electricity in passing will scintillate from the point in brilliant flashes, imitating the aurora borealis.

Experiment 118.—*Aurora borealis.* This experiment consists of a glass tube bent in the form of an arc, and capped at each end with metal; one end has a valve to exhaust the air. A piece of cotton or thread is stretched inside the tube, and connected with both caps. The current of electricity is passed direct from the machine if it is powerful enough; if not, charges from the jar may be used. The electrical light appears to radiate from the thread, which may be supposed to represent the denser atmosphere near the earth.

Experiment 119.—*Nobili's aurora borealis.* Take a wire insulated by being bound with silk, form it into a close flat spiral of twenty revolutions with the different coils in contact. When a charge from a powerful battery (No. 1) is passed through it, a vivid light will dart from the centre of the spiral. M. Nobili considers this electro-magnetic light similar to the aurora borealis.

Experiment 120.—*The meteor tube.* This is a long glass tube, exhausted of air, with a cap conductor at each end; the charge of a battery passed through it produces a spark of light very like an atmospheric meteor.

Experiment 121.—*The comet.* Take a sheet of black card; attach it to a piece of wood so that it will stand on its edge; perforate a hole with a pin, and bend the point of the pin to an angle of 90°; a black pin is best as it is not seen on the black card; fix the pin to the card so that the turned point is a short distance from the face; this may be done by tying several threads to the pin on the back side, and securing the threads to the card with sealing-wax. Tie the chains from the machine to the head of the pin; if the machine be now worked in the dark, a brush of light of comet-like form will be produced. With a small machine it is better to paste a slip of tinfoil behind the card, from one edge to within about half an inch or less of the point of the pin, and to connect the slip with the earth, to carry off the electricity.

EXPERIMENTS WHICH SHOW THE CHEMICAL EFFECTS OF ELECTRICITY.—This part of our subject possesses few items for popular amusement, which has been particularly our aim in the experiments already introduced. Generally speaking, chemical effects are much more strikingly produced by dynamic electricity, that is that of the voltaic battery. They are, however, of the same class with either kind of electricity, and consist of decompositions and compositions, the only difference being that voltaic electricity has the greater chemical power.

Experiment 122.—*To decompose water.* Take two pieces of fine wire insulated with gutta percha, and cut them off square with scissors; bind them together so that the points shall be exposed at about an inch asunder; place the whole in a glass tube filled with water, so that both points are under the water one below the other. Connect one wire with the outer coating of the charged Leyden jar, and bring the chain from the other by the insulated rod to the knob of the jar, so that a spark passes. If the points under water be observed, a globe of oxygen and hydrogen will be thrown off the point at each discharge. Two very fine insulated points of gold or platinum as conductors under the water answer best for this experiment.

Experiment 123.—*Recomposition of water.* For this we require a very strong glass globe, with conductors at opposite sides. If the globe be filled with two volumes of hydrogen and one of oxygen, and the charge of a Leyden jar passed, the gases will explode with a violent report, and the globe will be covered with moisture, the result of the combined gases.

Experiment 124.—*The electric pistol* is constructed to look like a pistol, the barrel being of ivory, and the handle a metal reservoir. Two opposite points of metal are inserted in the base of the barrel, each with a hook to connect the chains from the Leyden jar. The pistol is filled with the mixed gases oxygen and hydrogen, and is corked tightly. The charge of the Leyden jar may now be passed, and the cork will be projected with violence. This experiment may also be performed with coal gas, the explosion of course being less.

Experiment 125.—*Separation of iodine from its salt.* Steep a small lozenge-shaped piece of blotting paper in a saturated solution of iodide of potassium, and place it upon a piece of glass. Pass several charges of the Leyden jar through it, and brown spots will appear on the paper, showing the separation of the iodine.

Experiment 126.—*To decompose an oxide.* Place a small glass tube half filled horizontally with the oxide of tin on the table of the universal discharger, between the two points, at about an inch apart. Pass the charge several times from a powerful battery (No. 1). The tin will be partially revived and deposited on the glass.

Experiment 127.—*To decompose a sulphuret.* Take the sulphuret of mercury (common vermilion) and place it in a tube, as in the last experiment. Pass the charge of a small battery or large Leyden jar several times, and the mercury will be revived.

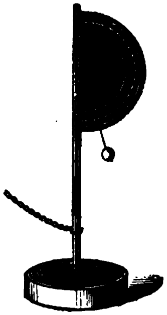
Experiment 128.—*To form nitric acid from the air by electricity.* Take a soda-water bottle, and fit a discharger into the cork, similar to that given in experiment 32, but with the points as far apart as the charge will pass. Place in the bottle a small quantity of solution of litmus; cork the bottle tightly, and pass repeated charges from the battery, rinsing the sides of the bottle after each charge with the litmus solution, which will become red, showing the formation of an acid from the contained air.

MAGNETIC EFFECTS OF ELECTRICITY.—The magnetic effects produced by the machine are much less powerful and effective than those of voltaic electricity; thus, whereas a piece of soft iron by voltaic electricity may be rendered a powerful magnet, it will scarcely be affected at all by the electricity of the machine.

Experiment 129.—*To magnetize a needle.* Place a needle across a wire through which a charge of electricity is passed from a battery or Leyden jar. After a few charges the needle will become magnetic and pick up another smaller needle. In this experiment it does not matter whether the needle touches the conducting wire or not, it will be magnetized if it is placed a quarter of an inch from it.

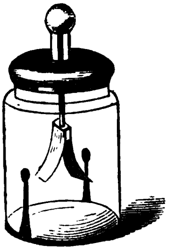
Experiment 130.—*To make a permanent magnet.* Make a paper case something like a squib case, only that it may be made with less paper. Wind the case entirely over with fine insulated wire, if in two thicknesses so much the better. Place loosely in the case a piece of hardened steel wire; pass several charges of the Leyden jar through the insulated wire, and the steel will become permanently magnetized in a low degree.

EXPERIMENTS FOR THE MEASUREMENT OF ELECTRICITY.



Experiment 131.—*Henley's electrometer.* We have seen in our experiments that light bodies tend to fly from other bodies similarly electrified. Henley's electrometer, or as it is more generally called, the quadrant electrometer, is formed upon this principle. It consists of a quadrant marked with degrees, placed vertically on a stand. From the centre of the quadrant, on a free axis, a light arm is projected with a pith ball at its extremity. When this instrument is in connection with any body charged with electricity, the

pith ball rises, and indicates on the scale the quantity of force or tension of the electrified surface.

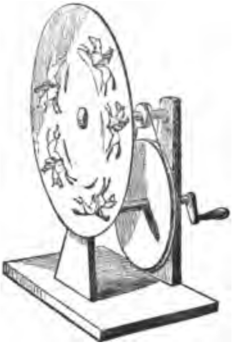


Experiment 132.—*Bennett's, or the gold leaf electrometer.* This most delicate instrument indicates the smallest conceivable amount of free electricity. It consists of a glass jar, through the top of which a glass tube is fixed, which insulates a metal rod, terminating with a ball at the upper end, and two gold leaves placed a short distance apart at the lower end. The under surface of the jar is connected with the earth and two slips of tinfoil which proceed some distance on opposite sides up the inside of the jar, in a line with the opening of the leaves of gold when they diverge. The action of this electroscope is most delicate. If a piece of sealing wax or glass, after being rubbed, be brought near the knob at the top, the leaves will instantly diverge.

Experiment 133.—*Colomb's torsion balance.* We have mentioned that Dr. Gilbert, the first modern electrician, measured the attractive force of electrically excited substances by a balanced needle. Colomb, to whom we owe the most profound system of modern measurement of electricity and its distribution on bodies, used also a balanced needle of refined manufacture, to which he gave the name of *the torsion* *balance*; it has been constructed in various ways, but uniformly consists of a fine needle of glass or shellac, suspended from its centre by a single web of silk or a very fine wire; at one end of the needle is fixed a small disc of sheet aluminium. An arc divided into degrees surrounds the needle, and at the zero of the circle a small gilt pith ball is fixed, which has a conductor leading outside the apparatus. At the top of the web is another divided circle which moves with the needle, so that the disc on the needle can be placed at any angle with the lower circle. To measure the electric tension of any object, it is brought in connection with the conductor to the gilt ball, when the needle is at rest with the balanced disc just touching it, the gilt ball becoming similarly electrified, repels the disc equal to the tension of the electricity which is measured on the divided circle.

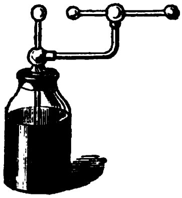
Experiment 134.—*To measure the electricity upon a fixed body with the torsion balance.* For this we require the *proof plane,* which is simply a small disc of metal foil fixed upon the end of a small stick of shellac or glass. This being applied to any body charged with electricity, a small portion may be taken from it nearly equal to that on the same amount of surface of the body, and carried by the proof plane to the conductor of the torsion balance, whereby the electric tension of the body from which it is taken may be measured.

Experiment 135.—*Simple electrometer.* Suspend two small equal pith balls by fine silk thread so that they just touch, and hang them from a piece of wire, bent to required form to attach it to the object, the electrical tension of which is wished to be ascertained; if the object is metal, the pith ball at each end of a piece of fine silk may be merely tied to it. As the balls become charged, they will be repelled from each other, and the separation may be measured by a paper scale placed at a distance behind them.



Experiment 136.—*The rapidity with which electricity travels.* Wheatstone discovered that electricity through a good conductor travelled at the rate of 288,000 miles in a second of time. It will be apart from our limited subject to describe the scientific instrument with which the research was made, but the principle of it forms a very simple instructive experiment. Prepare a circular disc of card about twelve inches diameter, and paste upon it various figures of any amusing description, as racing horses, carriages, boats, or anything of the kind; place the disc upon an axis fixed on a frame, so that it will revolve freely. Construct a very small pulley on the axis, and fix in the frame below a large pulley with axis and crank handle; connect the two pulleys by a band. Let the handle be turned, and the disc will move with great rapidity, so that the figures upon it will

appear as tinted lines; now extinguish the light, and while it is revolving rapidly, if a spark be discharged from the Leyden jar, the disc will appear to stand quite still, and the figures will be distinctly seen. The manner in which this experiment shows the rapidity with which electricity travels, and the short duration of the spark, is that the light does not last sufficient time for the disc to move an appreciable quantity. The same experiment is performed with the disc revolving very rapidly by clockwork; it nevertheless, during the passing of the spark, appears to stand quite still.



Separation of given quantities of Electricity.—Many experiments require small charges of electricity constantly; other experiments large consecutive charges of equal tension, to render them effective. There are several means of obtaining these results. A Leyden jar may be continually filling by the machine, but if a ball with connection through an experiment or otherwise, connected with the outer coating of the jar, be fixed at a given distance from the knob of the jar, the spark will pass and discharge the jar as soon as it is of sufficient tension to cross the air space between the knobs; thus, if the knobs be nearly close, small charges will pass frequently, if further, larger charges will pass less frequently; in all instances the charges will be equal. In this manner we may take small charges from a large battery, but the charge will be greater at the same distance in consequence of larger surface. For single large charges from the battery we may watch the rising of Henley's electrometer, and discharge when the pith ball rises to the degree that we consider sufficient.

The balance discharger. This discharge consists of a metal arm fixed to the stem of the jar. The arm is turned up to form a standard which carries the balance. The balance is a beam of metal centred like a scale beam, with a fixed ball at one end and a movable ball at the other. Above the standard a second arm is fixed, having a glass stem with a metal ball at the extreme end, the ball is connected with the outer coating of the jar or battery either through the experiment or otherwise. When the instrument is fixed, the ball of the jar, one ball of the balance, and the upper ball, are in a vertical line. The action of the balance is as follows :—the movable knob on the balance is adjusted, so that the knob over the jar shall rest upon its knob with a given pressure according to the charge required; or the upper arm may be made movable upon the standard, so that the charge may be adjusted by distance. When the jar is charged, the ball on the balance being also charged, is repelled until the tension is sufficient for it to pass the charge of the jar or battery, to the upper ball in connection with the outer coating, which it does through the beam and arm. Immediately after the charge is passed it falls again to the knob. This form of discharger is one of the best, as it always enables the charge to be observed as it accumulates. It can also be placed to large batteries as a kind of safetyvalve, to prevent overcharge at any time, and consequently breaking of the jar. There are two other quantity dischargers in use: Harris's unit jar and Law's electrometer; the particular merits of which our limited space will not allow us to enter upon.

THE TWO ELECTRICITIES.—We stated in the early pages that there were two kinds of electricity, which was shown by an experiment with a stick of wax and a stick of glass. It was not necessary to go further into the subject at the time, as it would only tend to hang a complication over our simple experiments; we return to the subject only to give a few experiments and make a few remarks. It was discovered by Franklin that one electricity could not be produced without the other, and that one machine would give off no electricity unless it was in connection with the earth, from which it could receive it, although the earth represents the negative electricity and our machine gives the positive; thus no electricity could be obtained from a machine made entirely of glass, as no part would conduct the electricity; therefore Franklin thought that there could be but one electricity, and that any body charged with it would be *positively* electrified, but if the electricity was taken from it it would be *negatively* electrified. Thus we have two words, positive and negative electricity; the positive being the vitreous and the negative the resinous; in nearly all experiments the positive and the negative act alike. We have given one experiment to distinguish one from the other, and will offer two others; the first is that generally made use of in practice.

Experiment 137.—*To distinguish the kind of electricity* *by the gold-leaf electroscope.* This instrument is a most delicate test, for the kind as well as the presence of electricity We rub a stick of sealing-wax and bring it gradually at a distance above the ball of the electroscope ; as we approach the ball, the gold leaves will diverge, which is caused by the sealing-wax attracting the positive electricity to the ball and repelling the negative electricity to the gold leaves, which causes them to diverge. If we now touch the knob with the finger, the negative electricity will be decomposed, and the leaves will collapse; if we now remove the sealing-wax, the electricity contained in the ball will spread over the leaves and cause them again to diverge slightly, and the electrometer will be charged with positive electricity. If we now bring any body charged with positive electricity, as an excited glass rod, near the knob, the leaves will diverge more, indicating positive electricity; but if we bring the piece of silk with which the rod was rubbed, the leaves will collapse, indicating negative electricity. A very slight friction will cause any object, if it is insulated from the earth, to be slightly charged with one kind of electricity sufficiently for the gold-leaf electroscope to indicate which.

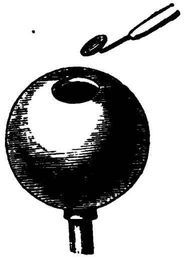
Experiment 138.—*Lichtenberg's figures.* This experiment illustrates the opposite electrical condition of the two coatings of the Leyden jar. Fix two glass rods firmly to the stem of a Leyden jar, and charge it with electricity from the machine. Hold the charged jar by the outer coating in the hand, and draw with pressure parallel lines at about equal distance apart, on a piece of vulcanite with the knob of the jar. Now take the jar by the glass rods, and draw with the outer coating parallel lines across the first lines at right-angles.

The jar may be recharged if much time is lost. Make an intimate mixture of finely ground flour of sulphur and red-lead, and scatter it upon the vulcanite. If the vulcanite is jarred to spread the powders, the sulphur will become attached to the positive lines, over which the knob of the jar has passed, and the red-lead will attach itself to the negative lines where the coating of the jar has passed. The sulphur will arrange itself in knots with diverging lines, and the red-lead will form circular spots. The experiment will show where the different electricities are distributed on the surface of the vulcanite.

DISTRIBUTION OF ELECTRICITY ON THE SURFACE OF CONDUCTING BODIES.

Experiment 139.—*Equal distribution of electricity on the surface.* If we take two metal globes, insulate them by suspending them by a silk cord, and charge one with electricity, it will attract the other from a certain distance. If it is allowed to touch, the electricity will be spread equally over the two, and they will repel each other a certain distance. If we now touch one to discharge the electricity, it will be attracted to the other half of the first distance; and if it touch, it will be repelled half of the first distance. This experiment shows that electricity spreads itself equally over any conducting body. If one of the globes be solid, and the other hollow of thin metal, the attraction and repulsion will be equal in each, which shows that electricity exists on the surface of bodies only.

Experiment 140.—*Electricity cannot be detected in the interior of bodies.* Take a thin metal globe, having a hole about an inch in diameter on the top, and insulate it by fixing it upon a glass rod, or laying it upon

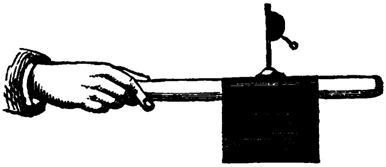


the bottom of a glass tumbler. After it is charged with electricity from the machine, if we take the proof-plane described at page 73, and apply it through the hole to any part of the interior of the globe, we shall not be able to move the leaves of the gold leaf electroscope the slightest by bringing the proof plane near the conductors, but if we touch the outside of the globe with the proof plane, it will, when brought near, cause the leaves to diverge considerably. This experiment proves that no electricity can exist upon the inner surface of conducting bodies.

Experiment 141.—*Electricity leaves one exterior for a farther exterior.* If we take the same globe and cover it with a pair of hollow metal cups, mounted on glass handles, and suddenly and quickly draw the cups asunder, we shall find that we have taken all the electricity from the globe, and that the cups now contain it. This experiment shows that a body charged with electricity cannot remain charged inside another conducting body.

Experiment 142.—*Another method of showing distri-*

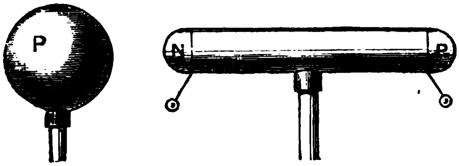
bution of electricity on the surface of bodies. Take a glass tube two feet long, and roll round it, the narrow way, a sheet of tinfoil two feet long and about nine inches wide, near one end of the tube. Hold the tube



by the end farthest from the foil, and charge the foil by the machine. Having the pith ball electroscope suspended by a piece of dry silk, if we now place it on the tinfoil, it will diverge considerably, showing high tension. But if we unroll the tinfoil so as to increase the exposed surface, and again apply the electroscope, we shall find the tension decreased in proportion as it is unrolled. If we again roll the foil up, we shall find the tension again increase as it formerly decreased. The quantity of electricity remaining the same, its tension will show less as the surface is greater. The experiment illustrates that the electricity rests on the surface and the surface only; otherwise, with the rolling up of the foil, some of the electrity would disappear, whereas the inner roll of foil contains no electricity, as the whole is always manifested on the outer surface.

Experiment 143.—*Faraday's experiment to show that electricity is manifest on the outside of bodies only.* Fit a metal ring on an insulated support, and attach to the ring a gauze bag, such as is used to catch butterflys; sew a silk thread to the bottom of the bag, and have a long end inside and outside. If the bag be drawn out one way and charged with electricity, it may be collected by the proof plane from the outside but not from the inside. If the bag be now drawn inside-out by the silk thread, the electricity will still be on the *outside*, that is, on the surface that was inside before, which showed no electricity.

ACTION OF ELECTRIFIED BODIES ON BODIES IN A NATURAL STATE. INDUCED ELECTRICITY.—We have shown in many of our experiments that electrified bodies attract bodies in a natural state. This is apparently but not really the case. What really happens is, that positively electrified bodies attract negatively electrified bodies, and vice versa. This is explained by another law in electricity that we have only mentioned, that of *induction*, or the power of an electrified body to induce or produce electricity in a non-electrified body. The electricity so induced being of the opposite kind to that in the electrified body in that part which is exposed to its influence.



Experiment 144.—*To show induced electricity.* Electrify an insulated metal globe with the machine, and place at a short distance from it a cylinder of metal, with rounded ends; suspend a pith ball from each end of the cylinder. It will be seen that the cylinder has become in an electrical state, although no elect-

tricity has passed from the globe, yet the pith balls rise at each end, and diverge away from the centre of the cylinder. Rub a stick of sealing-wax with cotton cloth, and bring it near the pith ball next the globe; the ball will be repelled by it, indicating that it is charged with the same electricity as the sealing-wax, that is, *negative;* but if the excited sealing-wax be brought to the pith ball farthest from the electrified globe, it will be attracted; thus indicating that one end of the cylinder manifests negative electricity, and the other positive; and that the negative electricity is at the end of the cylinder nearest the positively electrified globe, and that this electrified state is entirely induced by the cylinder being placed near the electrified globe; for if we remove the globe, no electricity will be manifest in the cylinder. If we had placed another cylinder near the end of the first, while under the influence of the globe, that would also have had electricity similarly induced. The positive and negative electricity, although equal on the cylinder, are not equally distributed. At near the centre of the cylinder if we place a pith ball, no electricity will be discovered. The attraction which accumulates the negative electricity at the end of the cylinder nearest the excited globe is greater on account of its nearness than the repulsion which drives the positive electricity to the distant end, so that the neutral point is between the centre of the cylinder and its negative end; thus the negative electricity is in a higher state of tension, and if the experiment remain for a long time, the negative electricity will therefore disappear first, and leave the cylinder weakly charged with positive electricity. But if we touch the end of the cylinder farthest from the excited globe with our finger, and thereby take off the positive electricity up to the natural point, we shall find upon afterwards removing the excited globe, that the cylinder is charged with negative electricity, that is, the opposite electricity to that of the excited globe.

INDUCED ELECTRICITY APPLIED TO CONDENSERS. We have been shown that the opposite electricity to that of the electrified conductor is induced in the nearest portion of another conductor through the medium of a non-conductor, which in our last illustration was the air between the two. We will give some experiments in which glass is the non-conducting medium, that will simply explain the theory of the Leyden jar and other condensers.

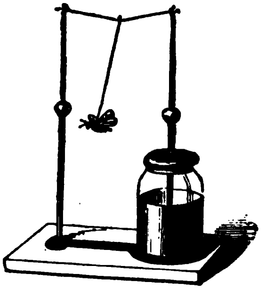
Experiment 145.—*A simple condenser of electricity.* Procure a pane of glass, two sheets of tin, and a book; lay the book on the table, then one sheet of tin, then the square of glass should project an inch or inch and a half on each side over the tin, then place the other sheet of tin. If the chain from the machine be laid on the upper sheet of tin without touching the glass, it may be caused to receive a powerful charge, which may be discharged either by uniting the sheets of tin by the discharging rod, or by connecting them by conductors through any experiment. This experiment will be seen to be similar to our magic picture; it is also similar to the Leyden jar, as we have only to imagine the whole rolled into a cylinder to form one; but what we wish to show is that it is similar to our first induction experiment in the last page, with the electrified globe and cylinder. In the globe and cylinder we have an electrified body which is a conductor; a non-conductor, the *air*; and then another conductor in which the electricity is induced through the air. In our condenser we have an electrified conductor, the upper sheet of tin; a non-conductor, the *glass*; and then another conductor of electricity in which the electricity is induced. If we place this lower sheet of tin on a sheet of glass, instead of on the book, we shall find that one surface will be charged with negative electricity next the glass, and the other with positive electricity away from it, as our insulated cylinder was in relation to the electrified globe; and therefore if we united the plates we should have no shock, as half the positive electricity on the upper plate would only spread on to the lower one; but as it stood upon the book, a conductor of electricity, it was like the cylinder when touched by the finger; the positive electricity was carried off to the earth, and the negative induced electricity remained facing the positive electricity, which induced it through the non-conducting glass, the union of which afterwards produces the shock or charge.

THE INSTANTANEOUS DISCHARGE AND THE SLOW DISCHARGE OF CONDENSED ELECTRICITY. In experiments with the discharger when the two coatings of the Leyden jar or other condenser are united by metal, it is called the *instantaneous discharge*. A Leyden jar may also be discharged slowly by a conductor carrying away the electricity in quantities equal to the surface of the body in relation to that of the jar. This is called the *slow discharge*.

Experiment 146.—Suspend a metal ball by a silk cord, so that it will be attracted by the knob of the charged

Leyden jar; place another knob at equal distance from the centre of gravity of the suspended ball, and let this one be connected by a conductor to the outer coating of the jar, either direct or through an experiment. The suspended ball will continue vibrating between the knobs until the force of electricity is exhausted.

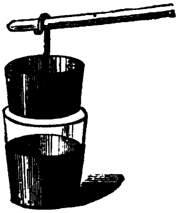
Experiment 147.—*The bell jar.* Instead of a knob as in the last experiment, place a bell on the jar, and another on the rod connected with the outer coating; the electricity will cause the ball to strike the bell more and more softly until the sound vanishes.



Experiment 148.—*The butterfly.* Place the charged jar and conductor to outer coating as in the bell experiment, but in place of the metal ball suspend a butterfly, cut out of pith, with painted paper wings; it will continue for a long time flying from ball to ball with gyratory motion and constant vibration of the wings, extremely life-like.

Electricity only retained by non-conducting bodies. By non-conducting bodies, we mean bodies that conduct electricity very little: there is no absolutely non-conducting body, but electricity is conveyed through metals with immense rapidity, but through glass and resins very slowly, and other substances in various degrees; but bodies that receive or conduct electricity slowly also part with it slowly, particularly to any but good conductors.

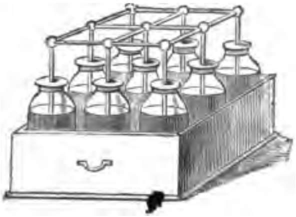
Experiment 149.—*Charged surface of non-conductors.* Take a dry tumbler or a large wine glass, and place the chain from the machine in the interior, and work the machine, and then remove the chain. Place several pith balls on the table, and put the glass over them, they will fly about in all directions, showing that the interior surface of the glass retains the electricity with which it was charged.



Experiment 150.—*The Leyden jar with moveable coatings.* This experiment shows that it is the glass that retains the electricity, and not the metal coatings; for this experiment a plain glass tumbler is taken, and sheet tin outer and inner coatings are made to fit loosely, so that either one can be easily removed; the inner coating requires a hook to enable it to be lifted out by a glass rod. If this jar be charged from the inside by the machine, and the coatings united by the discharger, the spark will pass, as with an ordinary Leyden jar; but if we charge the inner coating, and afterwards remove it by a glass rod, and lift the glass out of the

outer coating with the hand, the two coatings taken from the glass will give no spark. If we take them in our hand, or let them touch, they will become perfectly neutral. If we now place the jar in the outer coating, and return the inner coating to its place by the glass rod, by uniting the coatings with the discharger, a spark will pass just as if they had not been removed, showing that the electricity remains in the glass.

Secondary charge. The glass although it parts with the greater part of its electricity to such excellent conductors as metal coatings, it nevertheless will not part with its entire charge; hence what is termed the *secondary charge.* It is very important to take notice of this in using large batteries or jars, as it often amounts to a severe shock when taken accidentally. If we discharge a Leyden jar, and immediately afterwards apply the discharger, it will appear that no more electricity remains on the surface, but if we let it stand a few minutes, the electricity in the glass will have reached the surface, and another spark will pass. In very large batteries, or if the glass be thick in the jars, there will be even a third charge manifested by a faint spark.



General caution. In passing the electric fluid through the human body, it is never safe to pass more than that which is given off from a quarter of a superficial foot of coated glass. It is not safe to trust a large jar or battery in the hands of youth, for this reason we have made our No. 1, 2, and 3 machines with a small Leyden jar, so that no injury can be inflicted. Very many experiments may be performed without the battery, which is almost as dangerous as firearms in the hands of the young.

INDEX OF EXPERIMENTS, APPARATUS, ETC.

PAGE
Aurora Borealis, Ex. 118 . . 66
Ball Vacuum Tube, Ex. 108 . 61
Balloon, The Electrical, Ex. 48 34
Battery 88
Battle, Electrical, Ex. 92. . 54
Bead Chain, Luminous, Ex. 83 52
Bell, Electrical, Ex. 64 . . 48
Bell-jar, The, Ex. 147 . . 86
Bennett's Electrometer, Ex. 132 71
Book, The Luminous, Ex. 77 . 49
Bulb Vacuum Tube, Ex. 108 . 61
Butterfly, The Electrical, Ex. 148 86
Camphor Plant, The, Ex. 50 . 36
Candle, To light with a piece of ice, Ex. 20 . . . 24
Candle, To blow out, Ex. 52 . 37
Carbonic-acid gas, Spark through, Ex. 100 58
Chain, Conducting . . . 10
,, Luminous, Ex. 82 . 57
Charcoal Points, Ex. 22 . . 25
Charge with electricity a person, To, Ex. 4 . . . 18
Chime, The Electric, Ex. 66 . 44
,, Æolian, Ex. 67 . . 44
Cloud Conductors, Ex. 144 . 64
Coal Gas, Spark through, Ex. 101 58
Colomb's Torsion Balance, Ex. 133 72
Compound Vacuum Tubes, Ex. 106 61
Condensers, Construction of, Ex. 145 84
Conductors and Non-conductors 6
Designs, Electric, on card, Ex. 79 50
Diamond Jar, The, Ex. 73 . 47
Director 14
Dischargers 13
Discharge the Leyden Jar, To . 13
Distribution of electricity on conductors . . . 79
Dot Tubes, Electric, Ex. 74 . 48
Dutch metal, To burn, Ex. 16 . 23
Eggs, Luminous, Ex. 84 . . 52

PAGE
Electric Disc 8
Electricity always exterior, Ex. 140 79
Electrometer, Bennett's, Ex. 132 72
Ditto, Henley's, Ex. 131 . 71
Ditto, Simple, Ex. 135 . 73
Engine, Electric, Ex. 56 . . 39
Ether, To ignite, Ex. 19 . . 24
Ether, To ignite with a Spark from the Finger, Ex. 6 . 19
Faraday's Distribution Expt. 143 81
Fire House, The, Ex. 116 . 65
Fish, The Luminous, Ex. 88 . 53
Flash, Electrical, Ex. 117 . 66
Fly-wheel, Electric, Ex. 55 . 38
Franklin's Fly-wheel, Ex. 69 . 46
Free Chain, The . . . 12
Fruit, Luminous, Ex. 86 . . 52
Funnel and Syphon, Ex. 43 . 32
Gas, To light, Ex. 21 . . 25
Gases, Electricity through . 57
Gassiot's Cascade, Ex. 103 . 60
Glass, To perforate, Ex. 37 . 30
Gold Leaf Electroscope . . 72
Gold Leaf, To burn, Ex. 14 . 23
Ground Chain, The. . . 11
Gunpowder, To explode, Ex. 11 22
Head of Hair, Ex. 46 . . 34
Henley's Electrometer . . 71
Hydrogen, Electricity through, Ex. 96 58
Image Plate, Ex. 68 . . 45
Inclined Plane, Ex. 45 . . 33
Induction, Theory of . 11, 82
,, Ex. 144 . . . 82
Instantaneous and slow discharge 85
Insulation, Insulating supports 15
Insulated Pith-Ball Stand, Ex. 58 40
Iodine, Separation of a salt of, Ex. 125 69
Iron wire, To burn, Ex. 13 . 22
Ivory balls, Discharge through, Ex. 23 26
Leyden Jar 12

PAGE
Leyden Jar, with movable coating, Ex. 150 . . . 87
Lightning Jar, Ex. 111 . . 62
Luminous Globe . . . 57
Machine Chain . . . 10
Magnet formed by electricity, Ex. 130 71
Magnetize a needle, To, Ex. 129 70
Magic Picture, Ex. 3 . . 8
Meteor Tube, Ex. 120 . . 67
Mortar, The Electric, Ex. 38 . 30
Nitric Acid formed by electricity, Ex. 128 . . 70
Nitrogen, Spark through, Ex. 98, 99 58
Nobili's Aurora Borealis, Ex. 119 67
Non-conductors, List of . . 10
Obelisk, The Electric, Ex. 115. 65
Orrery, The Electric, Ex. 51 . 39
Oxide, To decompose an, Ex. 126 69
Paper, to perforate, Ex. 36 . 30
Phosphorescent Tube, Ex. 89 . 53
Pistol, The Electric, Ex. 124 . 69
Pith-Ball Stand, Ex. 60 . . 41
Plastic substances, Charge through, Ex. 39 . . 31
Positive and Negative Electricity 77
Ring, The Electric, Ex. 62 . 42
Sand plate, The, Ex. 44 . . 33
Scullers, The, Ex. 63 . . 42
Sea-fight, Ex. 93 . . . 55
Secondary Charge . . . 88
Serpentine Vacuum-tube, Ex. 109 62
Shock, to give to a person or persons, Ex. 1, 2 . . 17
Shower, Luminous, Ex. 42 . 32
Silver Balls, Discharge through, Ex. 24 26
Silver Leaf, To burn, Ex. 15 . 23
Snow-balling, Ex. 61 . . 42
Spark bending to avoid a non-conducting surface, Ex. 29 26
Spark detaches particle of the conductor, Ex. 35 . . 29

PAGE
Spark, Heating power of, Ex. 18, 19 23
Spark over a finely divided conductor, Ex. 31 . . . 28
Spark over a partially conducting surface, Ex. 30 . . 26
Spark over water, Ex. 27 . 26
Spark passing through a current of air, Ex. 32 . . 28
Spark passing through oil, Ex. 34 29
Spark passing through water, Ex. 33 28
Spark passing from a point to a globe, Ex. 28 . . 26
Sparkle Tube, The, Ex. 81 . 51
Spectrum, Electric, Ex. 76 . 49
Spider, The Electric, Ex. 57 . 41
Spiral Vacuum Tube, Ex. 104 . 60
Sportsman and Birds, Ex. 51 . 36
Star and Brush, Ex. 72 . . 47
Star Plate, The, Ex. 75 . . 48
Storm Picture, Ex. 90 . . 53
Sulphuret, To decompose a, Ex. 127 70
Swan, The Gentle, Ex. 9 . . 20
Swing, The Electric, Ex. 71 . 47
Thunder-clouds, Ex. 113 . . 63
Tin-foil, To burn, Ex. 17 . 23
Tin-tack Conductors, Ex. 80 . 51
Torsion Balance, Ex. 133 . 72
Universal Discharger . . 21
Vacuum, Attraction to the finger, Ex. 95 . . . 57
Vacuum, Electricity through, Ex. 94 57
Vacuum Tubes, Ex. 102 . . 59
Vacuum, Perfect, Ex. 110 . 62
Water, To decompose, Ex. 122 68
Wax Threads produced by electricity, Ex. 48 . . . 37
Wheatstone's Measurement Expt. 136 76
Whirl, The Electric, Ex. 53 . 37
Windmill, Electric, Ex. 54 . 37
Word Plates, Ex. 78 . . 50
Word Tubes, Ex. 107 . . 61

PRICES.

STANLEY'S PATENT ELECTRIC DISC AND EXPERIMENTS,

May be had of the Patentee Wholesale and Retail,

RAILWAY TERMINUS, LONDON BRIDGE, LONDON, S.E.

ALSO OF VARIOUS AGENTS.

	£	*s.*	*d.*
No. 1a consists of a Patent Electric Disc of the best make, 11 inch glass plate, polished mahogany frame, brass fittings; Leyden Jar, brass mounted; and the following 20 Experiments—Universal Discharger, Electric Bells, Pith Ball Stand, Magic Picture, Head of Hair, two Lightning Jars, two Luminous Vacuum Tubes, Spiral Tube, Windmill, Sportsman and Birds, Electrometer, Water Fuzee, Sparkle Tube, Bucket and Syphon, Electric Ring, Image Plate, and Swan	4	0	0
This Machine will perform 100 of the Experiments.			
Large Battery adapted to the above No. 1a.	2	0	0
With the above Battery, No. 1a Disc will perform all the Experiments given in the book.			
No. 1 consists of a Patent Electric Disc, 11 inch plate and fittings complete, Leyden Jar, and the following 18 Experiments—Universal Discharger, Electric Bell, Pith Ball Stand, two Lightning Jars, Luminous Vacuum Tube, Spiral Tube, Sparkle Tube, Whirl, Sportsman and Birds, Swan, Luminous Necklace, Electrometer, Water Fuzee, Blowpipe, Magic Picture, and Head of Hair .	2	10	0
This Machine will perform 80 of the Experiments.			
Battery adapted to the above No. 1	1	10	0
With No. 1 Battery the above will, under favourable circumstances, perform all Experiments in the book.			
No. 2, Patent Electric Disc, fitted with 9 inch plate, Leyden Jar and Discharger, with 9 Experiments—Lightning Jar, Sportsman and Birds, Pith-Ball Stand, Head of Hair, Electric Bell, Magic Picture, Luminous Vacuum Tube, Swan, Water Fuzee	1	5	0
This Machine will perform 70 Experiments in the book.			
Battery adapted to the above No. 2	1	0	0
With No. 2 Battery the above will perform 120 Experiments.			
No. 3, Patent Electric Disc, fitted with 7 inch plate and the 5 following Experiments—Leyden Jar and Discharger, Pith Balls, Magic Picture, Electric Bell, Head of Hair .	0	12	6
This Machine will perform over 50 Experiments in the book.			

All the above are packed in neat cases, which are strong enough for conveyance to the country.

PRICES OF SEPARATE APPARATUS AND EXPERIMENTS.

	£	s.	d.
11 inch Electric Disc, mahogany frame, brass mounts	1	10	0
15 ,, plate glass ditto, suitable for lectures	3	0	0
18 ,, ,, ,, ,,	4	10	0
24 ,, ,, ,, ,,	7	0	0
36 ,, to stand on the floor with clamps	12	0	0
Leyden Jars.—Battery of Leyden Jars, No. 15	3	0	0
,, ,, 24	5	0	0
Separate large Insulated prime Conductors, No. 1a, 5/-; No. 15, 12/6; No. 18, 20/-; No. 24, 40/-; No. 36	3	0	0
Batteries of large surface of most economical construction to order.			
Discharger, double-jointed with glass handle 3/-	0	5	0
Director, brass mounted 2/-	0	3	6
Insulating Stools 12/-	1	0	0
Small Insulating Tables	0	2	6
Universal Dischargers . . No. 1, 10/-; No. 2, 6/-; No. 3	0	3	6
Ex.			
23 Pair of Ivory and Boxwood Balls for Discharger	0	1	0
29 Vulcanite Disc for Discharger	0	0	6
32 Glass Blow Pipe	0	0	6
33, 34 Water Fuzee	0	0	6
37 Twelve Discs of Microscopic Glass	0	0	6
38 Electric Mortar . . . small size 2/-, large ditto	0	4	0
42 Bucket, perforated	0	2	6
43 Funnel and Syphon	0	1	6
44 Vulcanite Square and Tannic Acid	0	0	9
45 Inclined Plane . . . small size 2/-, large ditto	0	4	0
46 Head of Hair . . . . . . small 1/-, large	0	2	6
47, 49 Ball and Pin	0	0	6
48 Electric Balloon	0	1	6
51 Sportsman and Birds without stand 1/6, with stand 3/-,	0	6	0
53 Electric Whirl . small size 1/-, large ditto	0	2	6
54 ,, Windmill . . . . ,, 1/6 ,,	0	5	0
55 ,, Fly Wheel	0	2	6
56 ,, Engine	0	7	6
57 ,, Orrery or Planetarium . . small 5/-, large	0	10	0
58 Insulated Pith Ball . . . . . ,, 6*d*., ,,	0	1	0
59 Electric Spider and Insulated Pin	0	2	0
60 ,, Pith Ball Stand . . small 1/-, larger 2/-, large	0	3	0
61 ,, Snowballing	0	5	0
62 ,, Ring	0	2	6
63 ,, Scullers	0	3	6
64 ,, Bell to fit on Leyden Jar . . . 1/- and	0	2	0
65 ,, Four Bells fitted to Leyden Jar	0	5	0
66 ,, Chime	0	12	0
67 ,, Æolian Chime	0	15	0
68 ,, Image Plate with one figure . . 2/-, 3/-,	0	5	0
Extra Figures to the above, according to work, 1/-, 2/- to	0	3	6
69 Franklin's Electric Fly Wheel . . . . 6/-, large	0	9	0

Ex.			£	s.	d.
70	Electric See-saw	2/6 and	0	5	0
73	Diamond Jar	from 3/6 to	1	1	0
74	Electric Spiral Dot Tube	8 in. 2/6, 12 in. 4/6, 18 in.	0	10	0
75	,, Star Plate	4 in. 2/-, 6 in. 3/-, 9 in.	0	6	0
76	,, Spectrum	12 in.	0	6	0
78	,, Word Plates according to size and words	from 6/- to	1	1	0
80	Tin-tacks	per 100 2*d*., per 1000	0	1	0
81	Sparkle Tube	7 in. 1/6, 12 in. 3/-, 18 in.	0	6	0
82	Rusty Iron Chain, per yard, 8*d*. Coloured Glass Tube, per foot	1/- to	0	2	0
83	Bead Chains	1/-, 2/-	0	3	6
84	Egg Stand	1 egg 2/6, 2 eggs 5/-, 3 eggs	0	7	6
85	Chain of Wax Eggs		1	5	0
89	Exhausted Phosphorescent Tube		0	5	0
90, 91, 92, 93	Lightning Effects, &c., on Pictures	2/6 to	0	10	0
94 to 101	Luminous Globe	15/- to	1	10	0
	Air Pump for exhausting	8/6 to	0	15	0
103	Gassiot's Cascade	small 5/-, large	0	10	0
104	Vacuum Tube		0	2	0
104 105	Spiral, Zigzag, Bulb, &c., Tube	3/6 to	0	7	0
106	Compound Tubes	4/6 to	0	10	0
107	Word Tube, according to device.				
108	Ball Tube	6/- to	0	10	0
109	Serpentine Tube	6/- to	0	18	0
110	Perfect Vacuum Tube		0	15	0
111	Lightning Jar	small 1/6, larger 2/6 to	0	4	6
112	Sheet Lightning Jars	,, 1/6 ,, 2/6 to	0	4	6
113	Insulating and Conducting Stand, separate		0	2	6
	Thunder Clouds		0	1	6
117	Electrical Flask		0	7	6
118	Aurora Borealis		0	9	0
119	Nobili's Aurora Borealis		0	7	0
120	,, Tube	5/- to	0	9	0
120	Insulated Wire, Gutta Percha	per foot	0	0	3
124	Electric Pistol		0	4	0
131	Henley's Electrometer	2/6 to	0	5	0
132	Bennett's Gold Leaf Electrometer	5/- to	1	0	0
133	Colomb's Torsion Balance	10/- to	2	10	0
134	Proof Plane	1/- to	0	2	6
136	Wheatstone's Electrometer illustration	7/6 to	1	1	0
	Harris's Unit Jar	5/- to	0	10	0
	Balance Discharger	6/- to	0	12	0
138	Vulcanite Disc, 6×6, 2/-, Clamp for Jar stem		0	2	0
139	Pair of 2-inch Brass Globes		0	5	0
140	Hollow Globe, Insulated		0	4	6
141	Globe and Cups		0	12	0
142	Glass Rod and Roll of Foil		0	5	0
143	Faraday's Experiment on stand		0	5	0
144	Four-inch Insulated Ball and 15-inch Cylinder on stands		0	15	0
147	Bell Jar	3/6 to	0	5	0
148	Butterfly and Rod only, to use with stand shown 113		0	2	6

All the above experiments made to order on a large scale for lectures, &c.

ARTICLES SUPPLIED FOR CONSTRUCTION OF EXPERIMENTS.

		£	*s.*	*d.*
Tin Foil	per foot superficial, thin 4*d.*, stout	0	0	6
Electrical Cement	per stick, 6*d.*, 1/-,	0	2	0
Electrical Varnish	per bottle, plain, red and black	0	1	0
Insulated Gutta Percha covered Wire	per foot	0	0	3
Insulated Wire, covered with Silk or Cotton	per yard, 2*d.*,	0	0	4
Plain Copper Wire	per yard, 1*d.*,	0	0	2
Brass Chain	per foot, 2*d.*,	0	0	4
Amalgam	per box, 6*d.*,	0	1	0
Pith	per stick	0	0	2
Pith Balls, per doz. 9*d.*, Figures	1/- to	0	4	0
Pith Birds	per brace, 1/-,	0	2	0
Brass Balls	½ in. 6*d.*, ¾ in. 9*d.*, 1 in.	0	1	0
Brass Rod	per foot, ⅛ in. 6*d.*, $\frac{3}{16}$ in. 1/-, ¼ in.	0	1	6
Brass Tube	per foot, ½ inch 6*d.*, ¾ in. 1/-, 1 in.	0	1	6
Glass Cane	per foot, ¼ in. 3*d.*, ⅜ in. 4*d.*, ½ in.	0	0	8
Glass Tubes	per foot, ½ in. 6*d.* ¾ in. 9*d.* 1 in.	0	1	0
Thick Glass Jars with turned caps for Leyden Jars, 4½ in.	1/3, 6 in. 2/-, 8 in.	0	3	6
Electric Bells	each, 2*d.*, 6*d.*,	0	1	0
Sheet Gutta Percha	per foot, 8*d.* to	0	2	6

Every article for construction of Experiments, or any separate parts, supplied Wholesale and Retail.

W. F. STANLEY, RAILWAY TERMINUS, LONDON BRIDGE.

All goods packed with care, but W. F. S. will not be responsible for accidental breakage in carriage.

Country orders must be accompanied by a remittance or London reference.

P. O. Order pagable at London; cheques crossed, "London & Westminster Bank."

Foreign orders for cash only.

Butler & Tanner, The Selwood Printing Works, Frome, and London.

Second Edition, Just Published, price Five Shillings.

STANLEY'S TREATISE

ON

Mathematical Drawing Instruments.

OPINIONS OF THE SCIENTIFIC PRESS UPON THE FIRST EDITION.

"It is a practical and reliable treatise by the mathematical instrument maker to the government, in various departments, and contains a clear and sufficient description of all the drawing instruments in general use. . . . The information given is no mere paste-and-scissors work, but freshly written from personal knowledge, and therefore especially valuable." —*Builder*, April 12th, 1866.

"It is impossible to read what Mr. Stanley has to say on the defects and advantages of particular instruments without perceiving that he has expended much thought on the details of their construction, and no little ingenuity in the attempt to improve on existing arrangements. The book is original throughout."—*Engineer*, May 4th, 1866.

"A really practical work."—*Engineering*, March 23rd, 1866.

"A work of no mean importance, bearing on engineering education," etc.—*Mechanics' Magazine*, April 20th, 1866.

"Mr. Stanley, from his long practical experience in the manufacture of mathematical drawing instruments of all kinds is fairly entitled to be considered as an authority on the construction and uses of this class of instruments. In the neat little volume before us, illustrated by upwards of 200 woodcuts, he has collected together a fund of information which cannot fail to be of great assistance to draughtsmen. The treatise embraces the entire range of mathematical drawing instruments, from the simplest to the most complicated, and supplies full information as to the method of using them. We confidently recommend this work, the style of which is clear and concise throughout."—*Practical Mechanic's Journal*, May 1st, 1866.

MAY BE HAD OF ALL BOOKSELLERS.

SIMPKIN, MARSHALL & CO.,
STATIONERS' HALL COURT, E.C.

Butler & Tanner, The Selwood Printing Works, Frome, and London.